Research Report 1249

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INFORMATION MANAGEMENT FOR AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

Robert W. Blum, Cathleen A. Callahan, W. Peter Cherry,
Donald Kleist, Gregory Touma, and Gary Witus
Vector Research, Incorporated

HUMAN FACTORS TECHNICAL AREA

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May 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This executive summary presents synopses of seven documents produced in the second phase of a project to develop information management concepts and procedures for automated battlefield command and control (ABCC) systems. ARI Research Report 1248 describes considerations in and procedures for the management of contemporary ABCC systems. ARI Technical Report 458 presents an analysis of procedures for the extraction, summarization and presentation of critical information. (AD-A107 329)

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20. Abstract

ARI Research Note 80-12 describes an analysis of information flow in the Tactical Operations System (TOS), an example AB^C system. ARI Research Note 80-13 describes the mathematical model used in the information flow analysis. ARI Research Notes 80-14 and 80-15 describe the operation programming of the computer programs implementing the model. ARI Working Paper HF80-XX discusses design issues associated with the emerging All-Source Analysis System (ASAS) concept.

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Vector Research, Incorporated

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FOREWORD

The Human Factors Technical Area of the Army Research Institute aids users and operators to cope with the ever-increasing complexity of the man-machine systems being designed to acquire, transmit, process, disseminate, and utilize tactical information on the battlefield. The research is focused on the interface problems and interactions within command and control centers and is concerned with such areas as tactical symbology, user-oriented systems, information management, staff operations and procedures, systems integration and utilization, as well as issues of system development.

An area of special concern is the development of procedures for effective system control and utilization. The inevitable need for engineering tradeoffs during system design often results in systems which are unmanageable or which at best achieve only a small portion of their potential. Explicit attention to the procedures to be followed by the user can compensate for some of these problems, particularly if accomplished early enough in the development cycle. The present publication is one of several from a project with an initial focus on the Tactical Operations Systems (TOS) and an initial goal of the development of procedures for managing the flow of information in TOS. The present report provides an overview of work accomplished on the second phase of the project. The reorientation of the project, from a focus on TOS to a more general view of automated command and control systems, is described and second phase products are outlined.

Research in the area of information management is conducted as an in-house effort augmented through contracts with organizations selected for their unique capabilities and facilities for research in this area. The present study was conducted by personnel from Vector Research Inc. under contract DAHC19-78-C-0027 with program direction from Dr. Stanley M. Halpin and Mr. Robert S. Andrews. This effort is responsive to requirements of Army Project 2Q163739A793 and to the Combined Arms Combat Development Activity, Fort Leavenworth, Kans., and Communications R&D Command (CORADOCOM), Fort Monmouth, N.J. Special requirements are contained in Human Resource Need 80-305, Information Management Within the Tactical Operations System.

Joseph Zeidner

JOSEPH ZEIDNER
Technical Director

INFORMATION MANAGEMENT FOR AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

BRIEF

Requirement:

To provide an overview of procedure guidelines produced in previous research for divisions in the field to use in developing standard operating procedures for information management in the Tactical Operations System (TOS).

Procedure:

Eight reports describing research performed during the second phase of a 36-month project are summarized. The reorientation of the project to a more general view of automated command in control systems is also discussed.

Section 2.1 summarizes ARI Research Notes 80-12 through 80-15, which describe the purpose, approach, results, and methodology of an analysis of TOS and its planned communications support systems. Section 2.2 summarizes ARI Research Report 1248, which discusses considerations in and procedures for the management of contemporary Automated Battlefield Command and Control (ABCC) systems. Section 2.3 summarizes ARI Working Paper HF80-XX, which describes design issues associated with the emerging All Source Analysis System (ASAS) concept. Section 2.4 summarizes ARI Research Report 1250, which analyzes procedures for improving information summarization in a corps-level scenario. Section 2.5 summarizes the emerging results from ongoing research to determine the information needs of decisionmakers.

Utilization of Findings:

This research can be used to define and implement management procedures in a variety of information processing systems.

PREFACE

This document is one of eight reports which describe the work performed by Vector Research, Incorporated (VRI), and its subcontractor, Perceptronics, Inc., for the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) under the second phase of contract number DAHC19-78-C-0027. The work described was performed over 12 months of an anticipated 36-month three-phased project. The overall objective of the project has been to produce procedural guidelines to be used by divisions in the field in developing standard operating procedures for information management in the Tactical Operations System (TOS). As a consequence of the redirection of the TOS development effort in November 1979, the objective of this work was reinterpreted to include automated battlefield command control systems (ABCCS) in general, using TOS for an explicit example of the design, human factors, and management control considerations which must be addressed.

The VRI study team for phase II was comprised of Dr. Robert W. Blum (Project Leader), Ms. Cathleen A. Callahan, Dr. W. Peter Cherry, Mr. Mark G. Graulich, Mr. Donald Kleist, Mr. Mark Meerschaert, Mr. Gregory Touma, and Mr. Gary Witus. The Perceptronics team for phase II consisted of Dr. Michael G. Samet and Dr. Ralph E. Geiselman.

The authors wish to acknowledge the helpful contributions of Dr. Stanley M. Halpin and Mr. Robert Andrews, who monitored the study for ARI; and LTC L. Walker, MAJ A. Edmonds, and Mr. M. Carrio, who performed a similar function for that portion of the study effort which was jointly sponsored with ARI by the U.S. Army Communications Research and Development Command (CORADCOM).

The eight reports are as follows:

Blum et al., Information Management for an Automated Battlefield Command and Control System, ARI Research Report 1249 -- presents an overview of the project and the other seven reports.

Callahan et al., Guidelines for Managing the Flow of Information in an Automated Battlefield Command and Control System, ARI Research Report 1248 -- describes considerations in and procedures for the management of contemporary ABCC systems.

Geiselman and Samet, Guideline Development for Summarization of Tactical Data, ARI Technical Report 458 -- an analysis of procedures for the extraction, summarization, and presentation of critical information.

Witus et al., Analysis of Information Flow in the Tactical Operations System (TOS), ARI Research Note 80-12 -- describes the purpose, approach, and results of a TOS analysis which focused on TOS when integrated with a planned communications support system.

Witus et al., Description of the Tactical Operations System Information Flow Model, ARI Research Note 80-13 -- describes the representation of TOS used to develop the analysis package and the mathematics of the model.

Witus et al., User's Manual for the Tactical Operations System Analysis Package, ARI Research Note 80-14 -- explains the use and operation of the analysis package.

Witus et al., Programmer's Manual for the Tactical Operations System Analysis Package, ARI Research Note 80-15 -- describes the programming details of the package to facilitate modifications or transfer between host systems.

Cherry, WP, All Source Analysis System: Design Issues, ARI Working Paper HF80-XX -- a discussion of design issues associated with the emerging ASAS concept.

INFORMATION MANAGEMENT FOR AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

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List of Exhibits

INFORMATION MANAGEMENT FOR AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

1.0 INTRODUCTION

In the first phase of the project,[1] guidelines were drafted for the management of the information flow in TOS. The draft guidelines were to be tested in the second phase of the project on prototype equipment to be available for a planned operational test (OT-II) in FY80. When it became evident during phase I that the prototype equipment would not be available as planned, VRI proposed that its mathematical model of TOS, intended to support the development of the draft guidelines, be expanded to a mathematical surrogate for TOS during phase II. Concurrently, the TOS project manager's office at CORADCOM became interested in sponsoring the extension of the VRI model to encompass the communications system to support TOS. The model extension thus became an important feature of the phase II effort and the methodology which it contained when completed has provided a very useful means for examining the design characteristics of both TOS and its supporting communications.

The first application was a number of analyses of the communications support system conducted with the TOS model during the fall of 1979; the results of these analyses are summarized in a later section. In brief, it was found that digital message transmission error rates of more than about 0.8 percent could have been expected to cause significant degradations in TOS communications performance had the system been fielded.

As the analyses progressed for determining the effectiveness of the guideline procedures for managing TOS in the field, it became apparent that indicators of the status of TOS would have to be available continually if the manager were to be able to discern the nature and location of a system problem needing management attention. At the time of the Congressional Budget Action in November 1979, TOS did not possess among its design features the capability to provide the needed monitoring information from which to govern the system's tactical operations. Ample analytical support for that observation is provided in the summary report in chapter 2.0.

In parallel with the main efforts was a separately reported project conducted under subcontract to examine various summarization techniques for collapsing the bulk of a corpus of information. Among other good summarization procedures, shortening TOS message lengths could have had a significantly beneficial effect on reducing congestion in the communications system, as was learned during the first analysis effort. This work is summarized also in chapter 2.0.

Some ancillary research on determining information requirements of tactical decisionmakers was also undertaken during phase II and is still on-going. The work to date is summarized here.

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[1]For an overview of the first phase of the project, see <u>Information Management for the Tactical Operations System</u> (TOS), ARI Research Report 1228, October 1979.

Since November 1979, the project has expanded its perspective to generalize the research on TOS and its emerging conclusions to apply to the design of any automated battlefield command and control system (ABCCS). With this view firmly in focus, the project is proceeding apace.

2.0 SUMMARIES OF PRODUCTS AND RESULTS

This chapter presents summaries of the eight reports produced during phase II of this project. Section 2.1 summarizes ARI Research Notes 80-12 through 80-15--describing the purpose, approach, results, and methodology of an analysis of TOS and its planned communications support systems. Section 2.2 summarizes ARI Research Report 1248--considerations in and procedures for the management of contemporary Automated Battlefield Command and Control (ABCC) systems. Section 2.3 summarizes ARI Working Paper HF80-XX--a discussion of design issues associated with the emerging All Source Analysis System (ASAS) concept. Section 2.4 summarizes ARI Research Report 1250--an analysis of procedures for improving information summarization in a corps level scenario. Section 2.5 summarizes the emerging results from research in progress on determining the information needs of decisionmakers.

2.1 SUMMARY OF THE DIVISION TOS NETWORK MODEL AND ANALYSIS RESULTS

2.1.1 INTRODUCTION

The modeling of TOS automated processing and communications was motivated by a difficulty inherent in the design of any Automated Battlefield Command and Control System: the interactions among the subsystems and components are too complex to be understood by intuition alone, and are of such a nature that designing subsystems or components outside of the overall system framework leads to imbalances which impair system performance. Some design imbalances that may result from a failure to undertake a top-down and system-wide design program are: (1) excessive reliance on human management and intervention; (2) communications congestion and failure; and (3) extreme under-utilization of computer resources. As the TOS operational testing (OT II) drew near, it became clear that a systemic analysis of the proposed TOS was necessary to resolve certain issues including:

(1) the capability of the system to meet the user's requirements in a field environment;

(2) the performance tradeoffs among design options; and

(3) the need for human management and intervention.

To provide a means to address these and other issues, a mathematical model of a generic Automated Data Processing (ADP)/Communications system was developed which could be configured via a set of inputs to represent TOS. Computer programs were written implementing the model and supporting I/O routines. A TOS input file was created, and the model was used to analyze the operational behavior of the proposed TOS. The analysis approach and results are summarized in sections 2.1.2 and 2.1.3, respectively. The generic model and the representation of TOS are briefly described in section 2.1.4. The computer programs are described in section 2.1.5. Section 2.1.6 discusses some potential extensions to the model and its application areas.

2.1.2 ANALYSIS APPROACH

The analysis objectives for the proposed TOS were to:

(1) identify the critical system components, the components most likely to become choke points and cause degradation of the system;

(2) establish operating guidelines which would prevent choking at the critical components;

(3) evaluate the impacts of the field conditions on the performance of the critical components;

(4) examine the opportunities for performance improvement;

(5) examine strategies for selecting from among design options; and

(6) explore the human factors in the system operation.

The analysis plan defined a baseline case and a set of variations under which the system performance was examined. The baseline case and all variations used the network configuration as shown in exhibit 2-1, the user's projected peak hour traffic rates, and a realistic range of error rates for transmitter/receiver pairs (0 to 10 bits in error per thousand bits transmitted). The table in exhibit 2-2 displays the variations from the baseline case. These variations, taken in different combinations, produced 255 cases in addition to the baseline case. The analysis approach is described in detail in ARI Research Note 80-12, Analysis of the Information Flow in the Tactical Operations System.

2.1.3 ANALYSIS RESULTS

The results obtained for each of the analysis objectives are summarized below:

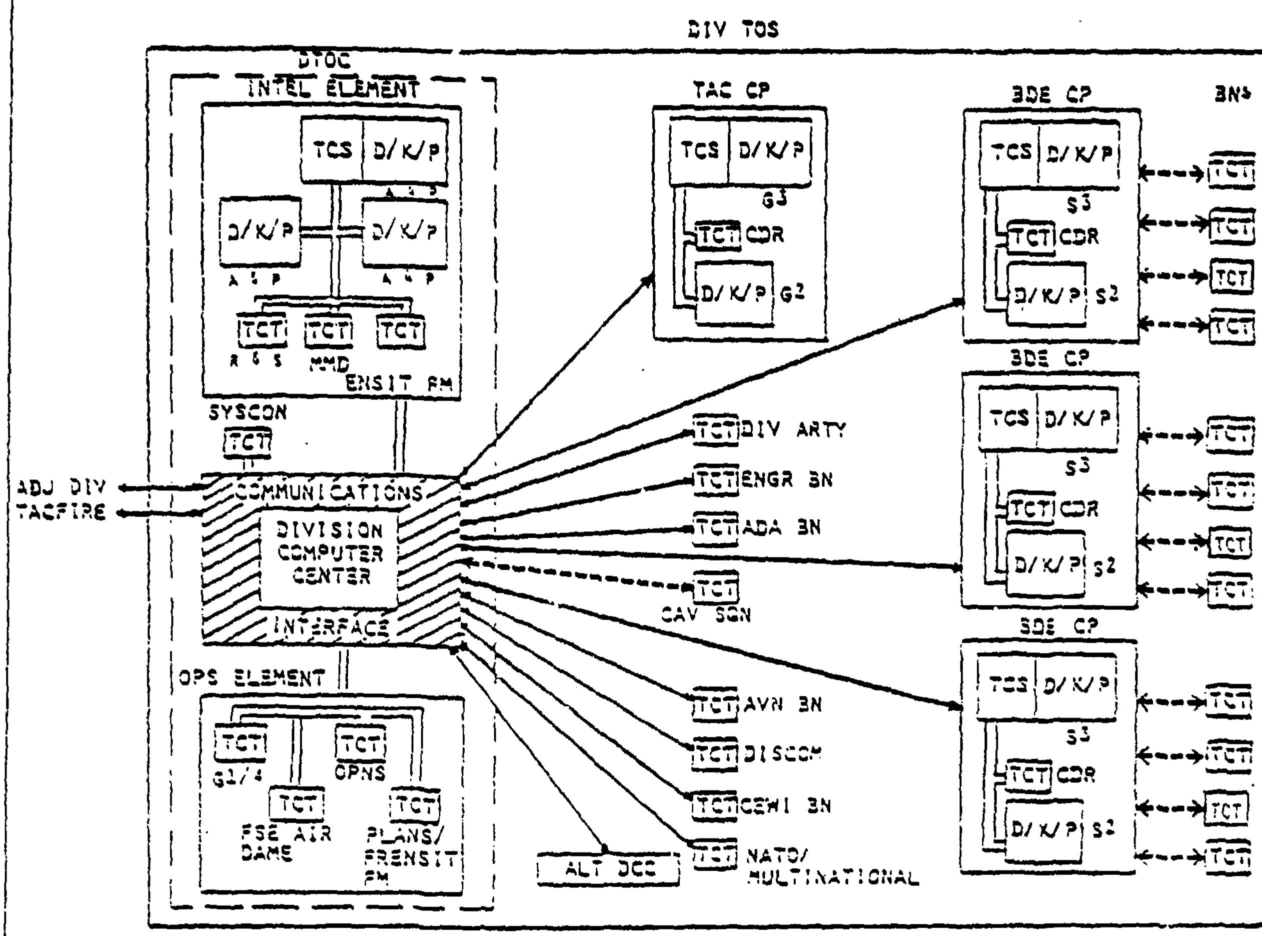
- The FM communications nets are the primary critical components and under various conditions are incapable of supporting their projected peak hour message traffic. The multichannel net and disk controllers are secondary critical components.

- Choking at the critical components with the associated long delays and likelihood of buffer saturation can be avoided by controlling the traffic rate to keep the utilization below 80 percent.

- The extent of degradation of the FM nets due to transmission interference, voice competition, and the use of retransmission stations is quantified and analyzed.

- Improved equipment, improved error detection and correction (EDC) procedures, and revised message formats could provide sufficient FM net capacity even under adverse field conditions.

EXHIBIT 2-1: DIVISION TOS NETWORK CONFIGURATION



LEGEND:

═══════	CABLE (FDX)
←——————→	MULTICHANNEL (FDX)
←- - - - - - -→	FM (HDX)

Source: A-Specs, April 1979

EXHIBIT 2-2: VARIATIONS FROM THE BASELINE CASE

	EXTENT OF CHANNEL SHARING WITH VOICE[1]	NUMBER OF RETRANSMISSION STATIONS[1]	TRANSMISSION RATE	ERROR DETECTION AND CORRECTION PROCEDURES	MESSAGE LENGTHS
Baseline Case	None	None	1.2 kbps for FM; 32 kbps for multichannel	Hamming Code and Time-Dispersed Coding (TDC)	Table IV, A-Specs
Variations	25 percent voice	3	0.6 kbps, 8.0 kbps for FM	Hamming Code and TDC with: 1) Multiple Blocking 2) Automatic Retransmission on Request (ARQ)	25 percent across-the-board reduction

[1]These factors affect only the FM nets.

- General guidelines are provided for selecting from among alternative improvements to the communications system.

- The human operator may become a system bottleneck or even reject the system if the operator is an active part of the communications loop.

The derivation of these results is summarized in the remainder of this section and documented more fully in the aforementioned research note.

2.1.3.1 Critical Components

A four stage procedure was used to identify the critical components:

(1) examine the sources of delay in the baseline case;

(2) examine component utilization in the baseline case;

(3) examine the ability of the system to meet the user's delay requirements in the baseline case; and

(4) consider impacts of further degradation from adverse field conditions.

The chart in exhibit 2-3 shows the breakdown of the expected total delay in transmitting and processing a message sent from a battalion in contact to the Division Computing Center. The FM net accounts for almost 98 percent of the delay at zero error rate, and the percentage is larger at higher error rates. The delay at the FM net consists of the time a message spends waiting to get on the net and the transmission time. The transmission time consists of overhead to establish the link and time to transmit the body of the message. As the error rate increases, the probability that a message must be retransmitted due to errors increases, and hence the transmission time increases. As the transmission time increases, the fraction of the time the net is busy increases, and consequently the waiting time increases.

A second approach to identifying the critical components is to examine the fraction of time that the various components are engaged. A chart showing the maximum utilization of various types of network components is presented in exhibit 2-4. No components other than the FM nets are busy more than 10 percent of the time, while at a five bits per thousand error rate the utilization of the Cavalry Squadron FM net exceeds 80 percent.

The user's requirements statement provided a range of maximum tolerable delays taking into account variations in message length, network configuration, and traffic intensity. As shown in exhibit 2-5, the average delays on some of the FM nets exceed the upper limit of the tolerable range at lower error rates than would cause the average multi-channel delay to exceed the lower limits.

EXHIBIT 2-3: BREAKDOWN OF EXPECTED DELAY

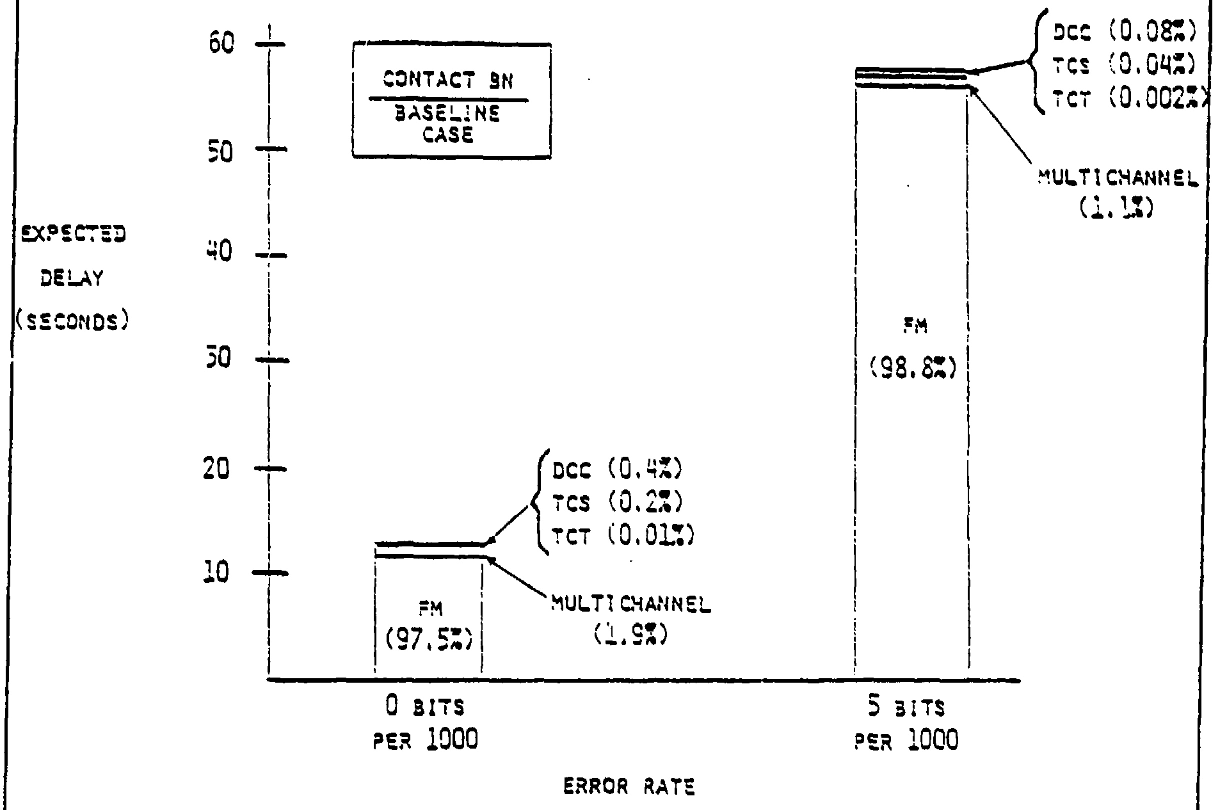


EXHIBIT 2-4: COMPONENT UTILIZATIONS

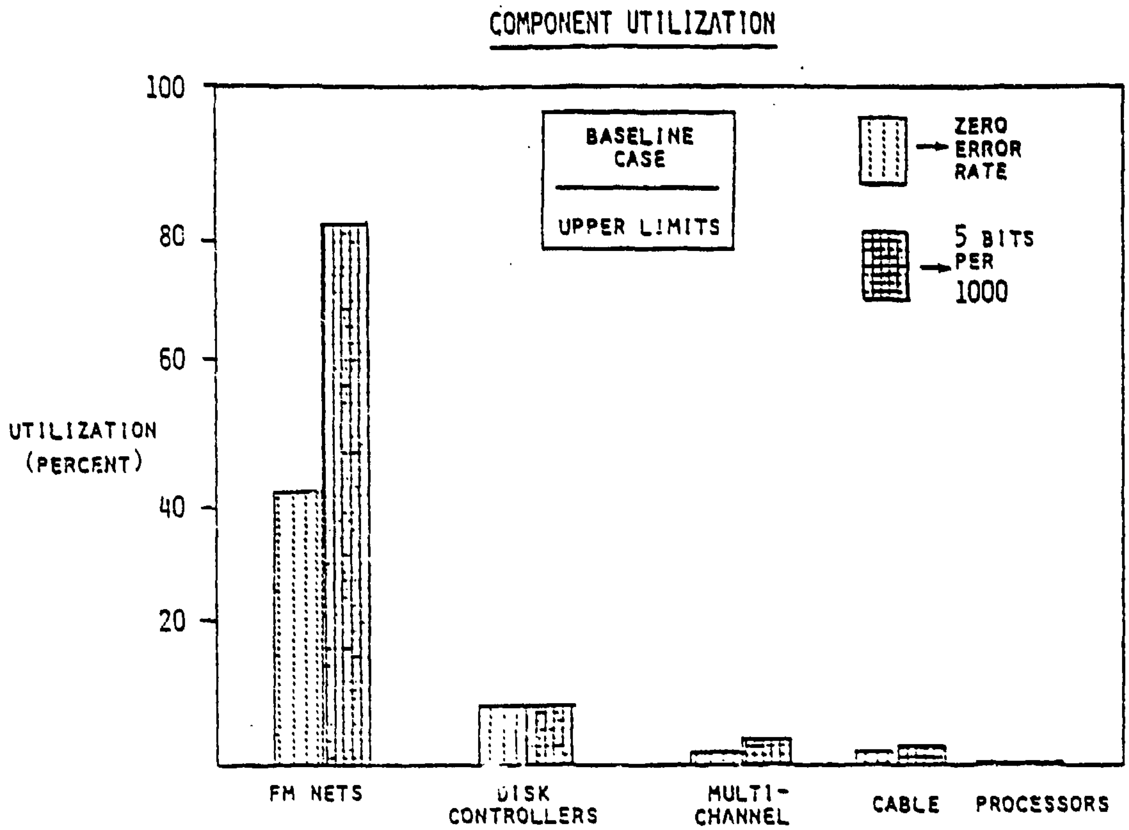


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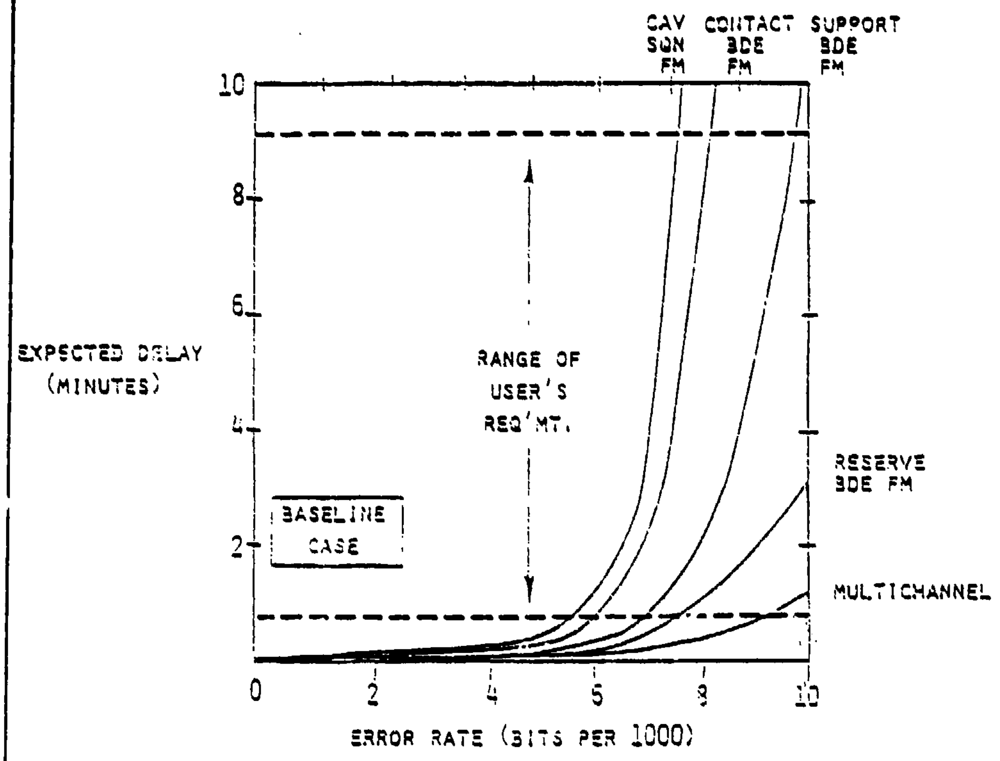
EXHIBIT 2-5: EFFECT OF TRANSMISSION ERROR RATE ON EXPECTED DELAYS



Based on the foregoing analysis, the FM nets were identified as the primary critical components. Furthermore, the performance of the FM nets can be severely degraded by adverse field conditions. For example, the FM nets are to be shared with voice transmission and hence are not 100 percent available for data transmissions. In addition, retransmission stations are used to extend the range of some FM nets. The use of retransmission stations requires a longer overhead time to establish a link, and the multiple transmissions produce a compounded error rate.

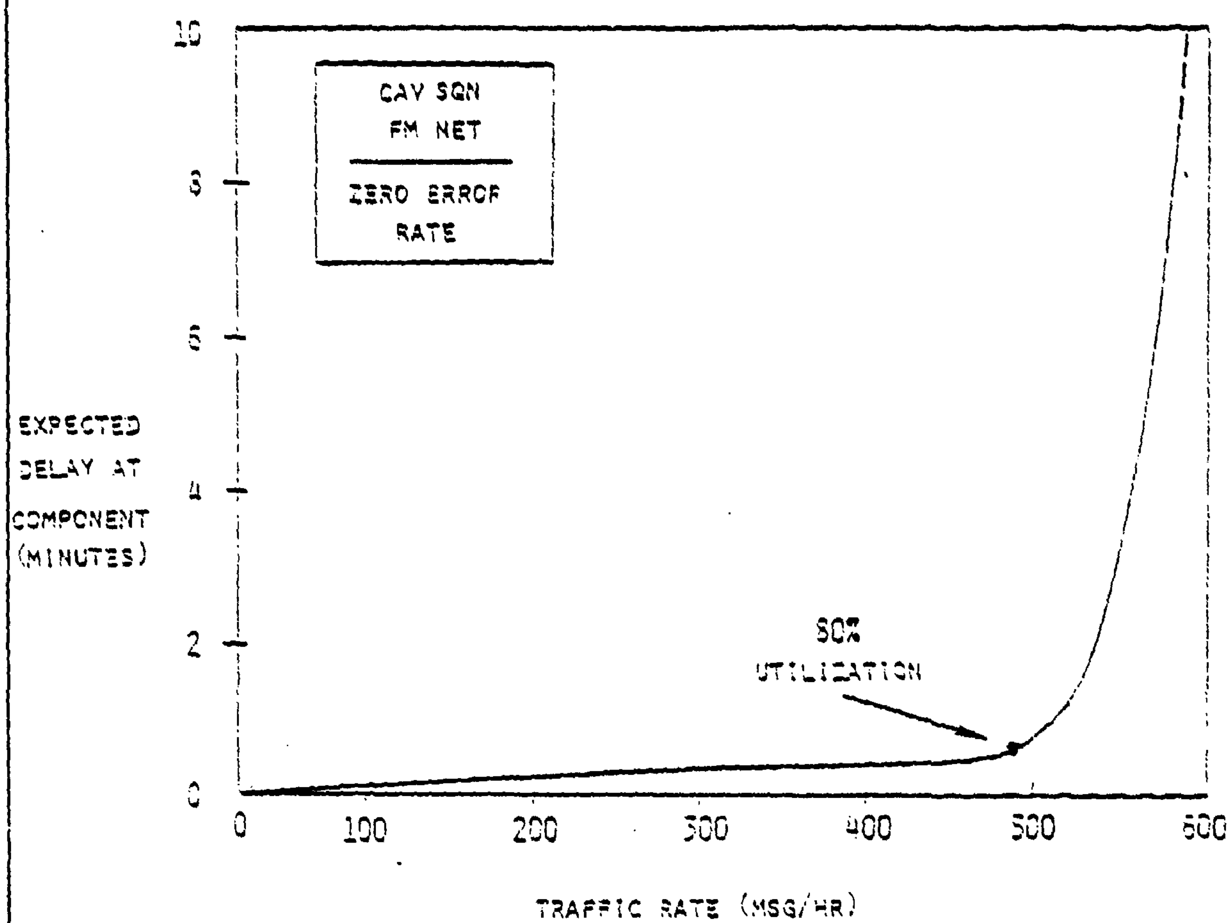
The multichannel net is, like the FM nets, susceptible to transmission errors. Due to the higher transmission rate (32 kbps for multichannel vs. 1.2 kbps for FM) and shorter link-up overhead (0.1 seconds for multichannel vs. 1.5 seconds for FM without retransmission stations), the multichannel net is able to operate effectively at error rates much higher than could be tolerated on an FM channel. The multichannel net does not become seriously congested until error rates in excess of 15 bits-per-thousand are reached.

The congestion level at the disk controllers is dependent in part upon the system software. The software design was not sufficiently mature by November 1979 to permit definitive analysis of the congestion at the disk controllers. The disk controllers are slow devices and unless the software was designed to minimize the demand on the controllers, the utilizations could easily be as high as the 8 percent shown in exhibit 2-4. This potential for overload motivated the identification of the disk controllers, along with the multichannel nets, as secondary critical components.

2.1.3.2 Operating Guidelines

The provisional TOS standard operating procedures [See ARI Working Paper HF79-1: <u>Information Management in the Tactical Operations System (TOS)</u>] provide for system control via control of the rate of user access to the system. By this means the System Controller can control the traffic rate on any net. The FM nets exhibit a characteristic response curve relating the expected delay to the traffic rate on the net. An example of this response curve for the CAV SQN FM net is shown in exhibit 2-6. The response curves for the other FM nets differ slightly as a consequence of the different mix of messages travelling over each net. The curves do, however, have some important characteristics in common. Expected delay responds linearly to changes in the traffic rate when the net is operated below 80 percent utilization, the curves exhibiting a knee beyond 80 percent utilization. Traffic rate is, therefore, a nearly linear control for expected delay so long as the net is operated below 80 percent utilization. Similar response curves define the relationship between expected queue length and traffic rate. The operational capacity of the net is defined to be the traffic rate which produces a utilization of 80 percent. A guideline for avoiding performance degradation due to congestion on a communications net is to keep the demand within the operational capacity.

EXHIBIT 2-6: SIGNIFICANCE OF 80 PERCENT UTILIZATION



2.1.3.3 Field Conditions

Various field conditions affect the performance of the FM nets. Foremost among these are the presence of transmission errors and the use of retransmission stations. Exhibit 2-7 shows the effects of the transmission stations. The net can support the projected peak hour load up to an error rate of approximately 5 bits-per-thousand.

It is likely that a cavalry squadron on a covering force or flank security operation will use several retransmission stations to communicate with its division headquarters. Retransmission stations increase the link-up overhead time and produce a compounded error rate. Equipment tests and theoretical computations indicate that at the error rates under consideration, "n-1" retransmissions produce a cumulative error rate of approximately "n" times the error rate for a single transmission. Exhibit 2-8 presents graphs of the CAV SQN FM net capacity with zero and three net retransmission stations. The x-axis is the error rate for a single transmission. The retransmission stations severely degrade the net's capacity: with the retransmission stations the net cannot support the required traffic at error rates above one bit per thousand.

2.1.3.4 Opportunities for Improvement

A number of options for improving the net performance were examined. These included hardware improvements, various software and transmission protocol improvements related to error detection and correction and message reformatting. The analysis examined the impacts of these options on the capacity vs. error rate curves of an FM net under the baseline and adverse field conditions. The effects of two classes of improvements are shown as examples: a higher transmission rate on FM and improved forward error correction (FEC). The current FM radios transmit data at 1200 bits-per-second (1.2 kbps). Exhibit 2-9 shows what could be achieved with 8 kbps radios, and the limiting case of radios with an infinite transmission rate. Increasing the transmission rate to 8 kbps achieves most of the potential gain since at high transmission rates the message overhead accounts for most of the transmission time.

TOS has the option of sending multiple copies of a message under one link-up overhead. Retransmission is requested by the receiving node only if the same character is undecipherable in each copy of the message. The default option is single blocking (SB)--one copy per overhead. Exhibit 2-10 shows the net capacity under single, double, and triple blocking. Multiple blocking reduces capacity at low error rates since more bits are transmitted, and as a consequence the projected peak hour load cannot be supported with triple blocking. With double blocking the net can function at error rates above 20 bits-per-thousand--well beyond the anticipated range of error rates due to sources other than enemy jamming. The presence of jamming or the use of retransmission stations requires the use of more effective procedures.

EXHIBIT 2-7: BASELINE CAPACITY

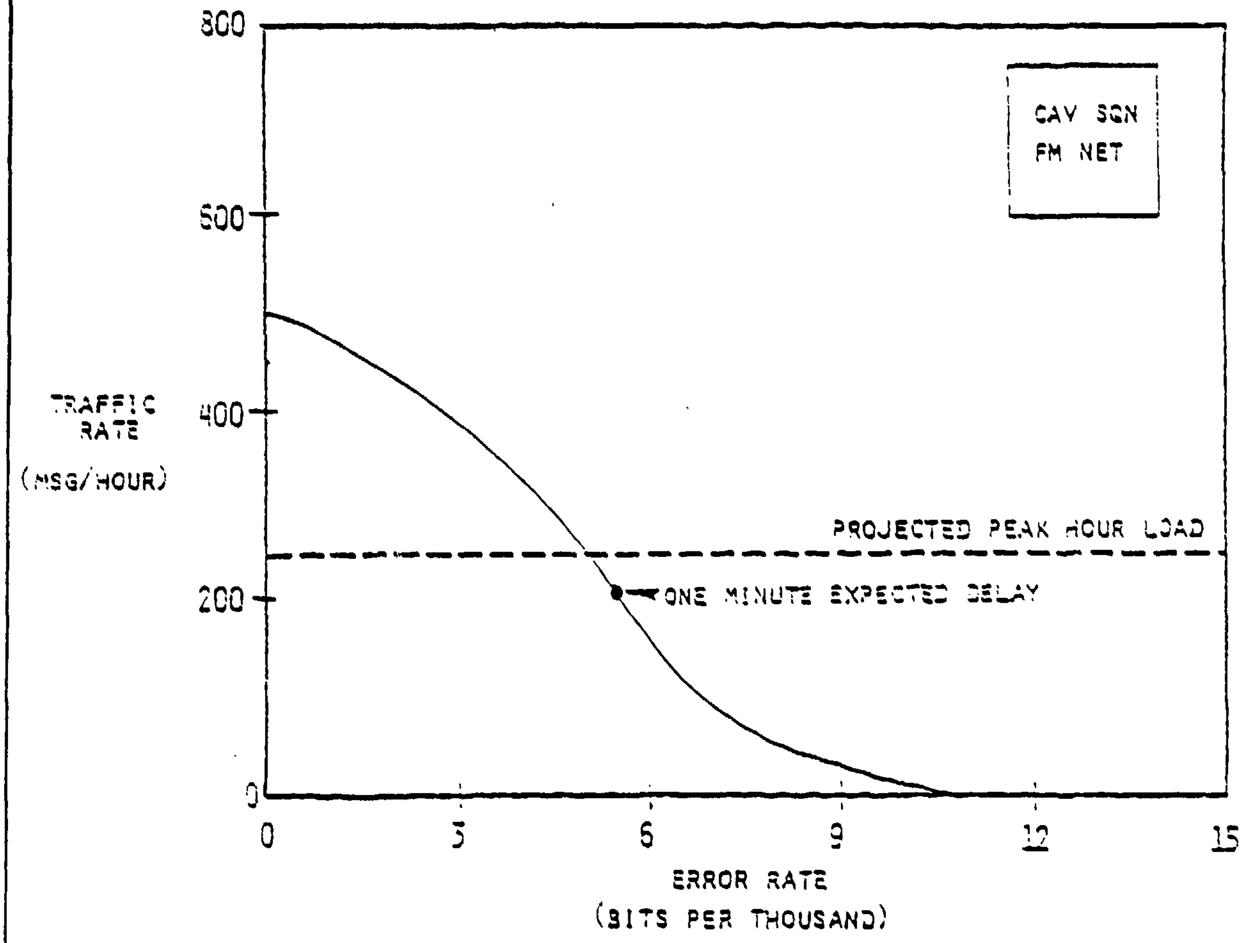


EXHIBIT 2-8: EFFECT OF RETRANSMISSION STATIONS ON CAPACITY

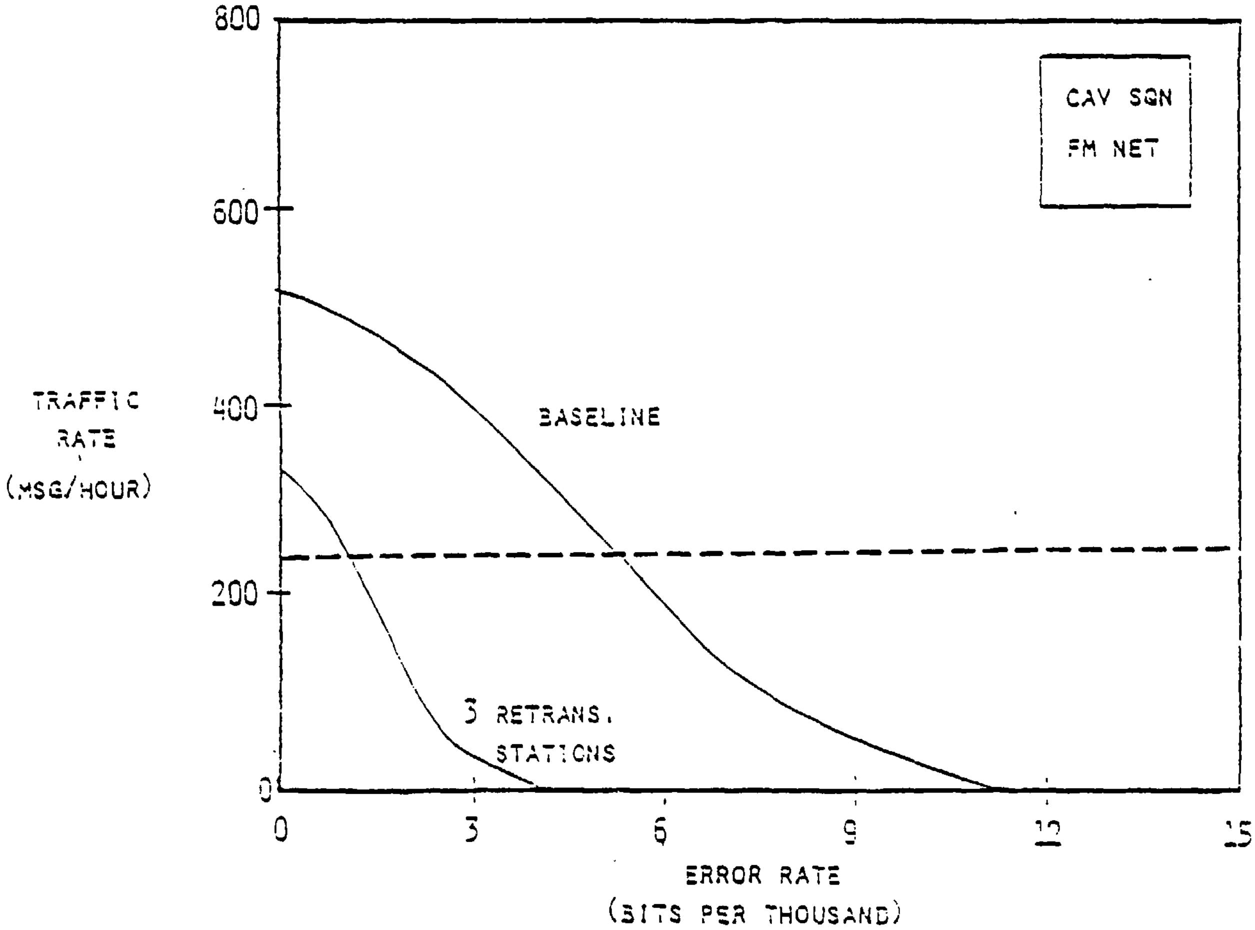


EXHIBIT 2-9: EFFECT OF TRANSMISSION RATES ON CAPACITY

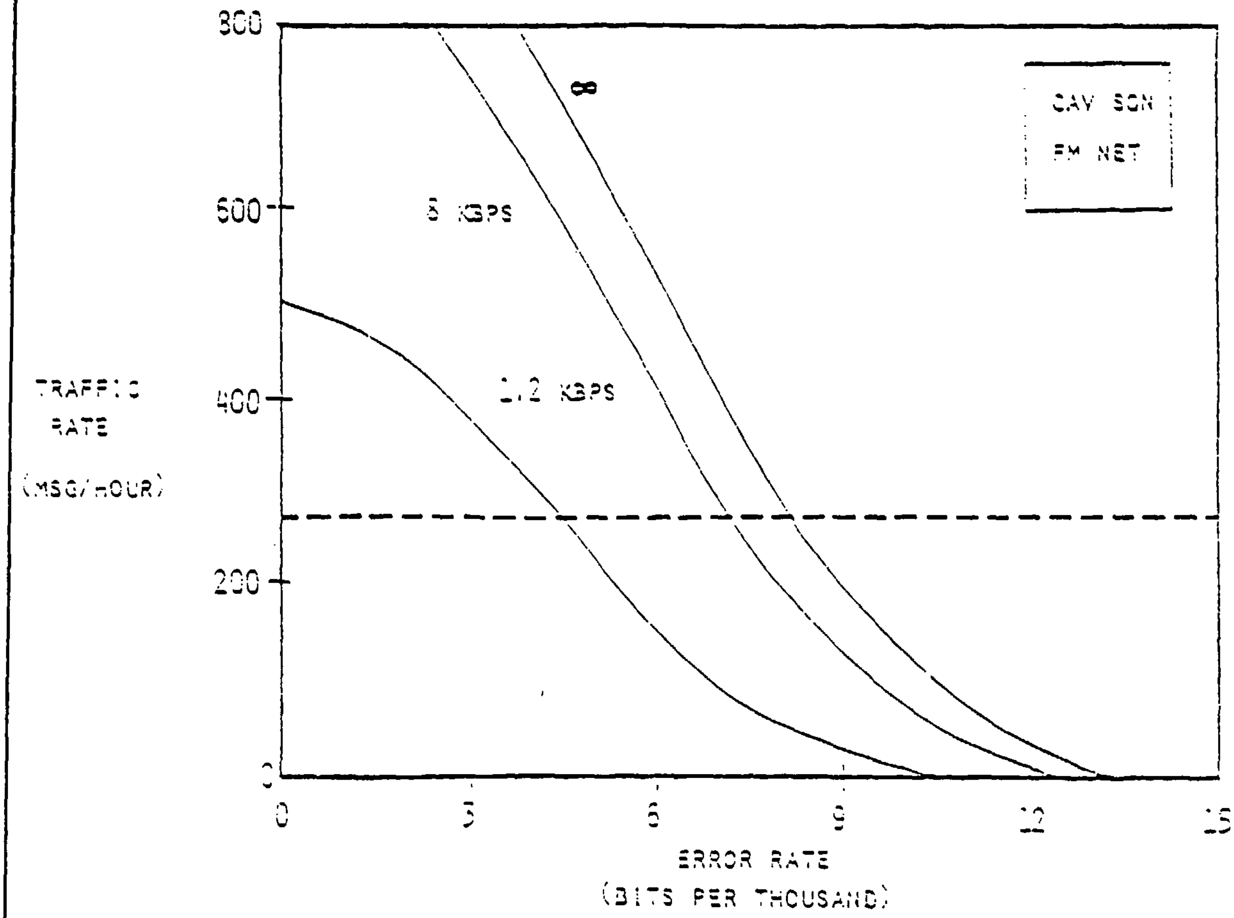
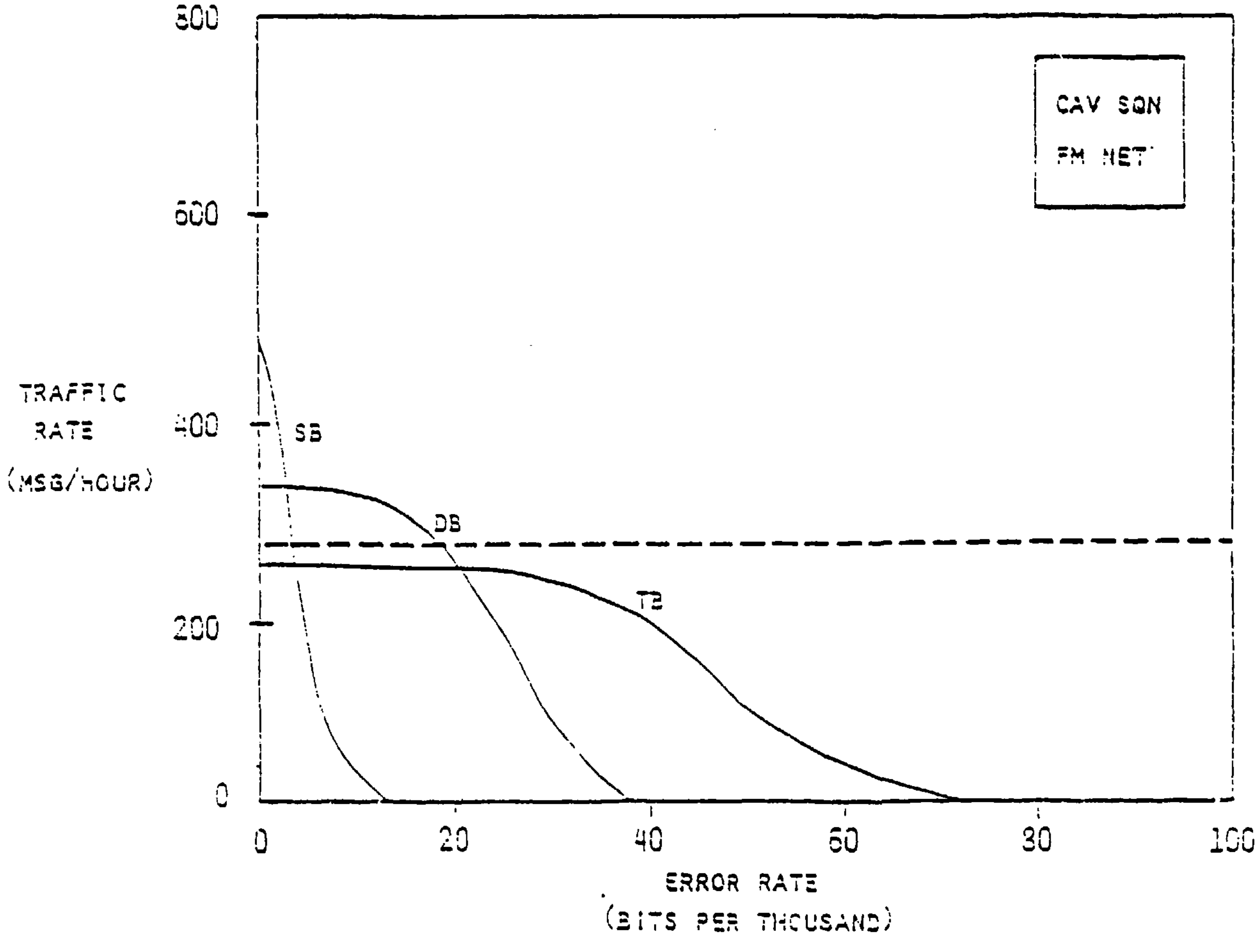


EXHIBIT 2-10: EFFECT OF MULTIPLE BLOCKING ON CAPACITY



2.1.3.5 Selection Strategies

This section develops an approach and a set of guidelines to aid the system designer in selecting design options to pursue from a set of alternatives. Given a set of field conditions and a shopping list of possible system improvements, the "opportunity for improvement" can be defined as the increase in the range of error rates under which the projected peak hour load can be supported (see exhibit 2-11). Having defined the opportunity, the relative value of a single option is the fraction of the total opportunity that is achieved with that single option. In some cases, a single improvement is capable of achieving as much as 70 percent of the total opportunity. Sometimes no single improvement has significant impact, in which case pairs of improvements must be considered. Alternative shopping lists were examined under alternative field conditions to provide a basis for developing guidelines for design selection.

Two illustration cases are presented. Exhibit 2-12 presents the analysis of an FM net without retransmission stations or voice competition, with a shopping list of various software improvements. Hardware improvements--faster radios--were not considered. The use of the single option of double blocking achieves about 50 percent of the opportunity for improvement. The use of two options--triple blocking and a 25 percent reduction in message length--achieves 95 percent of the opportunity. Exhibit 2-13 examines the CAV SON FM net degraded by three retransmission stations. As shown, without a combination of hardware and software improvements, no significant fraction of the opportunity can be achieved.

Several strategic guidelines were developed from these and other examples.

- Selections should be zero-based. In particular, the best single improvement might not be a component of the best pair.
- Improvements must be selected on a case-by-case basis.
- Different hardware or field conditions will favor different software options.
- The maximum increases may be far more than is required; hence the user's requirements should be considered during system design.
- Finally, the system designer should consider an integrated program of hardware and software development.

2.1.3.6 Human Factors

The TOS communications plan requires that operators monitor the communications system performance. If the transmitter tries and fails three successive times to access the net, or if the receiving node sends back three successive NAKs (non-acknowledgements) for a message, the transmission is terminated and the operator notified. No further automatic processing of the message occurs until the operator's instructions are received. These procedures

EXHIBIT 2-11: SELECTION STRATEGY CONCEPT

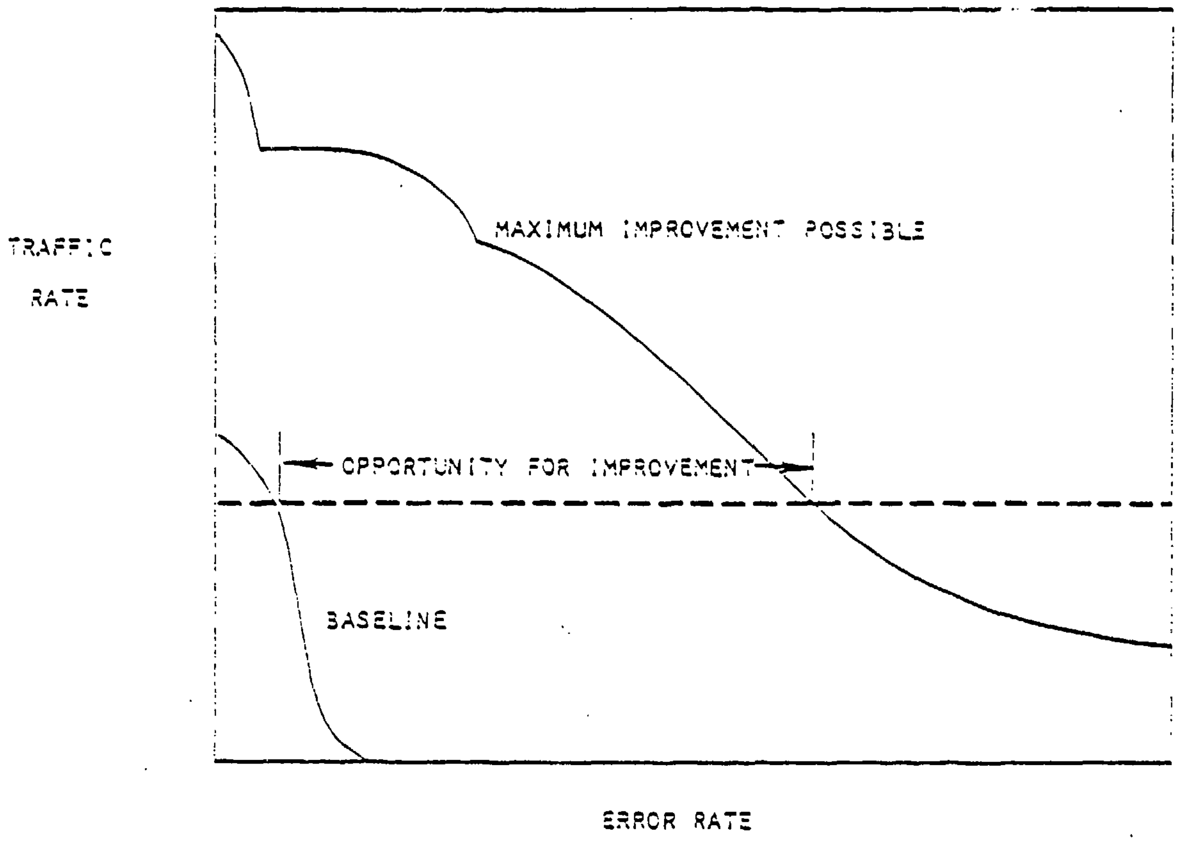


EXHIBIT 2-12: CAV SQN FM NET CAPACITY

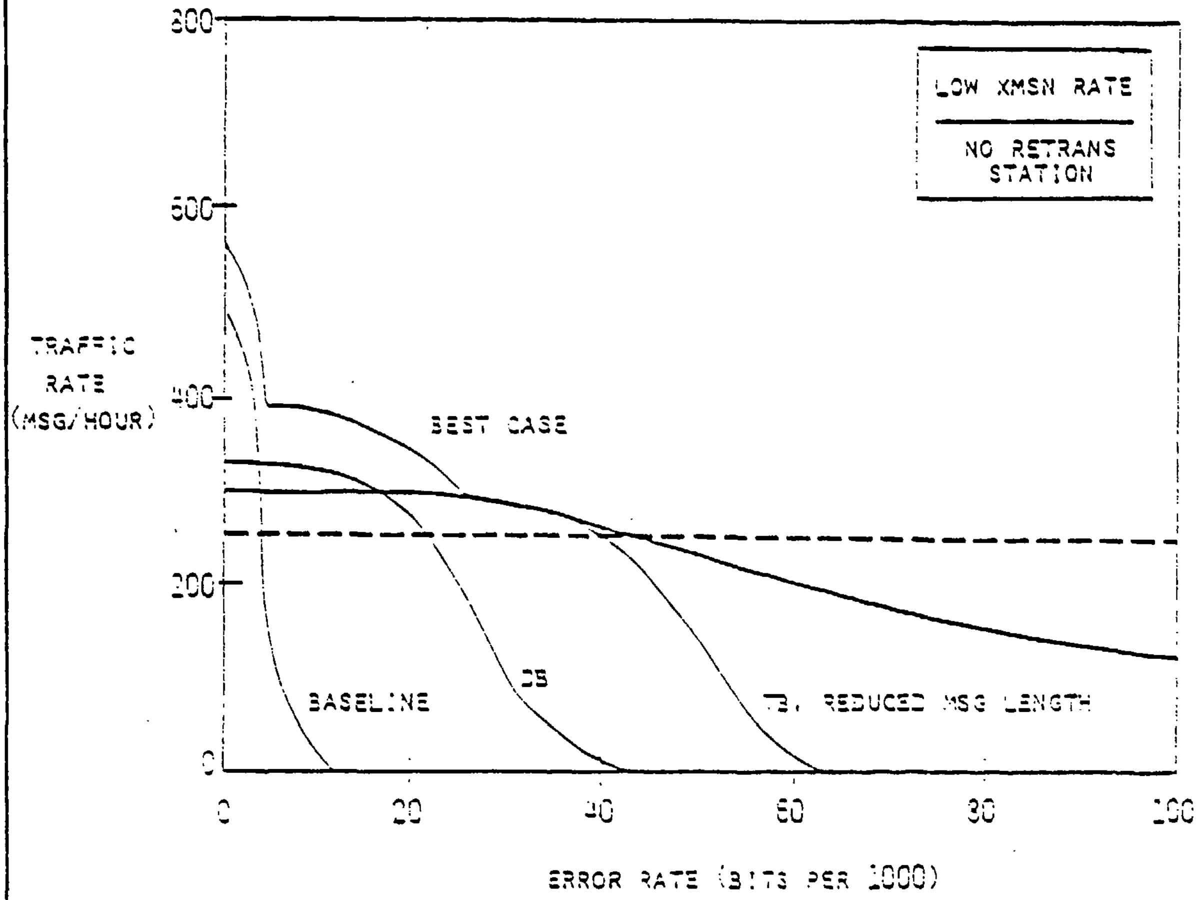
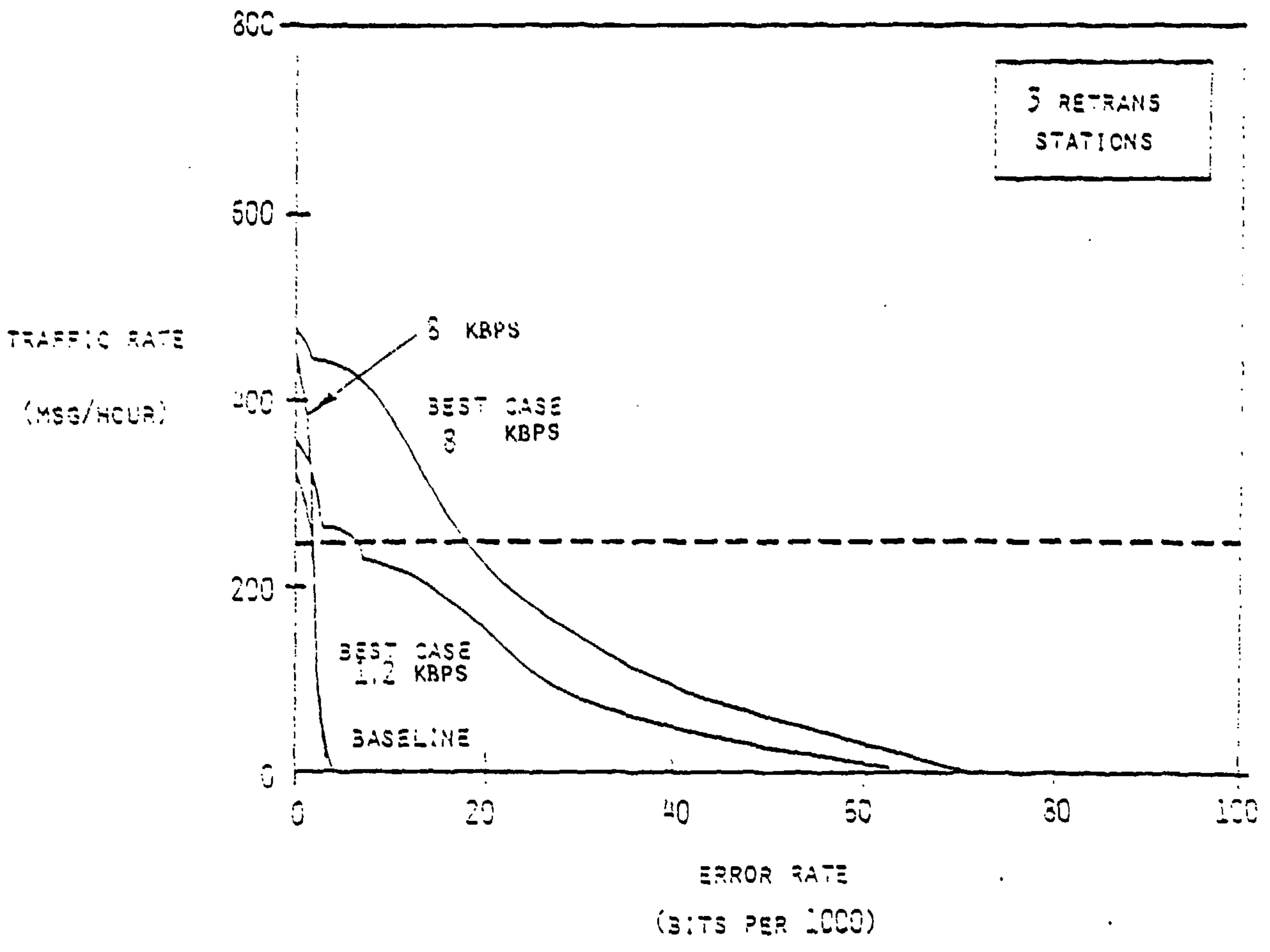


EXHIBIT 2-13: CAV SQN FM NET CAPACITY



are a rule-of-thumb for commercial applications where they are intended to provide a means to detect a degraded link and to prevent a degraded link from monopolizing a channel. However, commercial applications are not required to function under the adverse field conditions to which a military communications system is subject. The long delays associated with human decisionmaking and response make it imperative that the human role in data transmission be minimized in order to meet the timeliness requirements. Furthermore, the burden placed on the operator by these requests for instructions may lead to rejection and hence failure of the system.

The graph in exhibit 2-14 plots the probability that operator intervention is requested as a consequence of the channel being unavailable. The exact position of the curve lies in the shaded region and is determined by the amount of time between successive tries to establish the link. The figure in exhibit 2-15 shows the probability that user interaction is required due to three successive NAKs as a function of error rate in the baseline case. These two charts are combined in exhibit 2-16 which shows the aggregate probability that user intervention is required each time the transmitter tries to send a message. It is difficult to quantify the magnitude of the impact of human factors. It is clear, however, that the system must be designed to avoid operator overload. The role of the human in an automatic data processing system should, perhaps, be restricted to executive and input/output functions.

2.1.4 MODEL DESCRIPTION

The model is a mathematical model of a generic ADP/Communications system. The following six system functions are modeled:

(1) input/output;

(2) message routing;

(3) node-to-node communication;

(4) central data base management (storage and retrieval);

(5) human and automated message generation; and

(6) human and automated message filtering.

The purpose of the model is to provide a means to predict the steady state system performance from a set of inputs describing (1) the engineering characteristics; (2) the network configuration; (3) the operational procedures; (4) the user demand; and (5) the environmental factors. The steady state system performance is the performance level to which the system will converge over time when operating under stable conditions. The fundamental system performance measures are the utilization, expected queue length, and expected delay at selected system components. Other performance measures can be calculated from these basic performance statistics.

- Utilization is the fraction of time a component is busy.

EXHIBIT 2-14: SYSTEM DEMAND ON THE USER:
USER TOLD NET IS OCCUPIED

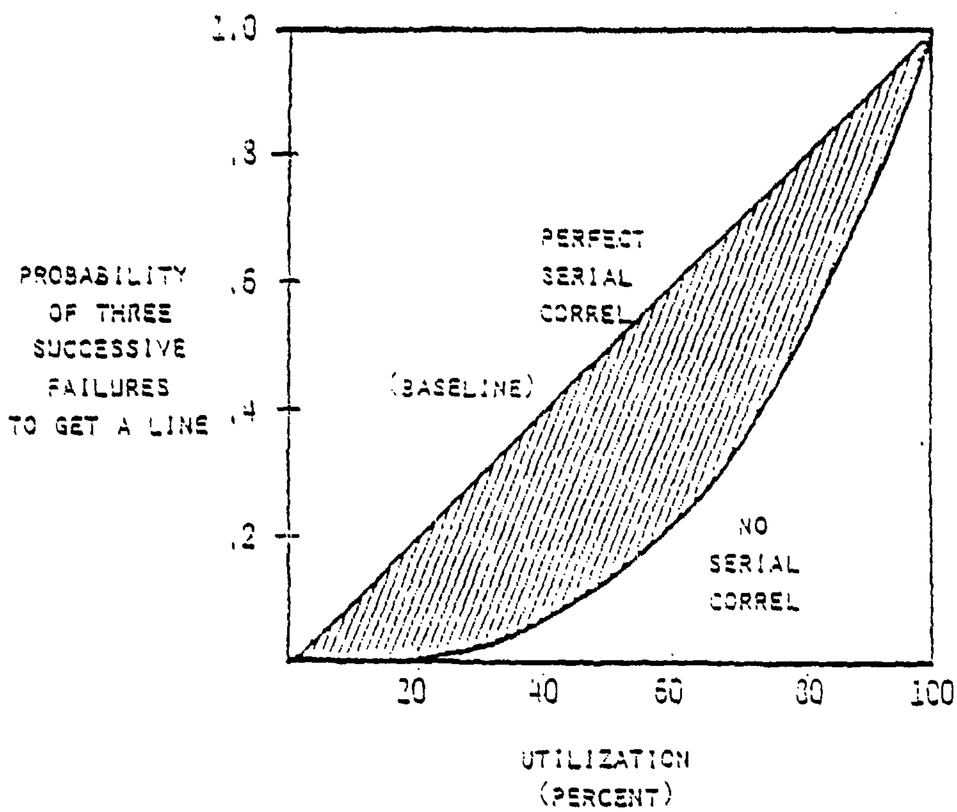


EXHIBIT 2-15: SYSTEM DEMAND ON THE USER:
USER TOLD MESSAGE WAS GARBLED

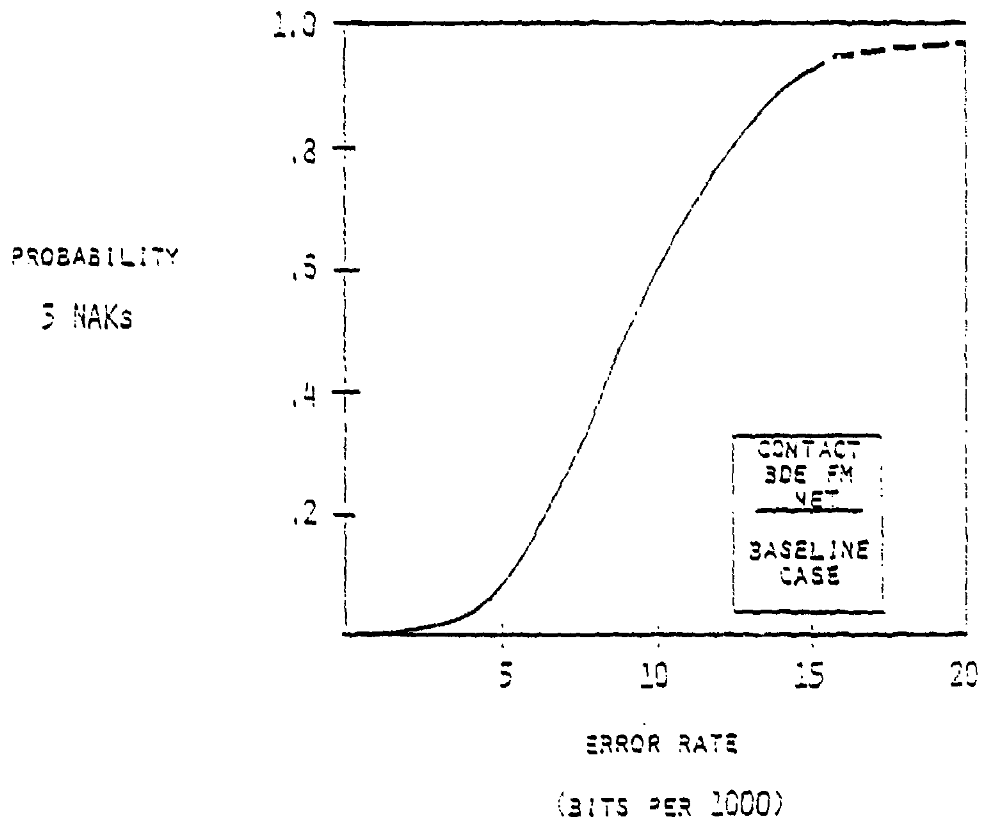
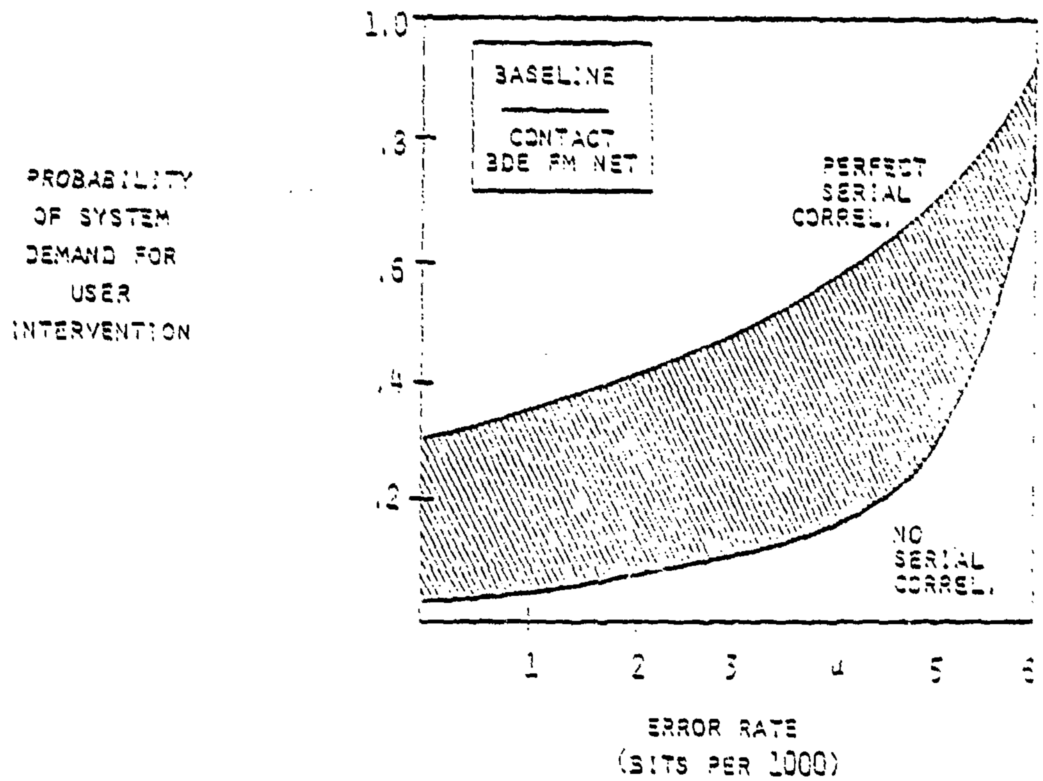


EXHIBIT 2-16: SYSTEM DEMAND FOR USER INTERVENTION



- **Expected queue length is the average number of messages waiting for service at a component.**

- **Expected delay at a component is the sum of the average service time for a message and the average time a message spends awaiting service.**

Due to limitations in time and resources, it was necessary to place restrictions on the scope of the model. First and foremost, the model represents the interactions among subsystems and components, but does not incorporate engineering models of the components. Instead, the engineering characteristics of the components are inputs to the system model. Second, the performance measures are computed only for the major system components: (1) the communications nets; (2) distributed processing nodes; and (3) the central processing node responsible for maintaining and searching the data base. Third, within a given network configuration each terminal node is assumed to have a single route connecting him with the DCC. Fourth, all messages are assumed to be of equal priority. Fifth, the model does not represent finite buffers at processors. Sixth, human factors are not incorporated into the model. (Consequently, the model computes only equipment delays and does not address the issue of whether or not humans could or would use the system efficiently.) The load on the operator is examined, however.

In order to perform the analysis, the model was specified to represent TOS. Message routing reflected the network configuration, the hierarchical review routing rules, the use of distribution lists, and the use of SRI (standing requests for information). Node-to-node communication reflected the use of multichannel (FDX), cable (FDX), and FM (HDX) communications devices and their different characteristics such as transmission rate, keying sequence overhead, and protocols. Transmission errors and the use of error detection and correction procedures (such as Jamming code) are part of node-to-node communication. Central data base management represents the storage, search, retrieval, and accountability procedures used in the Division Computing Center (DCC) to maintain and query the data base. Human and automated message generation represents the processes of human users generating messages as well as automated response messages generated at the DCC. Human review and filtering represents the hierarchical review function at Brigade and filtering at the DCC. The model and its specification to represent TOS are documented in ARI Research Note 80-13: Description of the Tactical Operations System Information Flow Model.

2.1.5 DESCRIPTION OF COMPUTER PROGRAMS

The model was implemented as a package of four computer programs to be run interactively from a terminal. The first program is used to create a data file specifying the system to be examined. The second program formats and displays a data file. The third program is used to modify an existing data file. The fourth program performs the computations required by the model and displays the outputs. All of the programs prompt the operator for responses. All of the programs are written in ANSI standard FORTRAN with internal commentary. The programs are documented in ARI Research Note 80-14: User's Manual for the Tactical Operations System Analysis Package, and ARI Research Note 80-15: Programmer's Manual for the Tactical Operations System Analysis Package.

2.1.6 MODEL AND APPLICATION AREA EXTENSIONS

In order to provide a more useful design support capability, the model can be expanded along three dimensions: (1) Generality; (2) Detail; and (3) Diagnostic Capability. The generality of the model can be extended to represent such features as:

- distributed data base;
- packet switching;
- communications management;
- human performance;
- finite memory and memory management.

The detail with which critical processes are represented can be increased to provide a more realistic representation, to incorporate new data, or to represent alternative procedures. Some areas in which the detail of the model can be extended are:

- electromagnetic environment;
- EDC procedures;
- transmission protocols;
- data base management;
- communications management.

Finally, the diagnostic capability of the model can be improved by producing additional outputs such as

- transient system response;
- memory utilization;
- frequency of undetected transmission errors;
- frequency of buffer saturation;
- frequency of failure to access a net.

To date, the applications of the model have been restricted to evaluation of the performance of a proposed design, and the evaluation of tradeoffs among alternatives. There is, however, a broader range of potential applications. Application areas for the model include:

- performance evaluation of a proposed design;
- tradeoff evaluations among alternative designs;

- support for the design of a balanced set of user's requirements;
- support for the design of system specifications;
- support for the design of operational tests;
- support for the design of on-line management and control procedures;
- identification of data requirements for on-line management and for performance evaluation;
- identification of likely critical areas in system design.

2.2 SUMMARY OF GUIDELINES FOR CONTROL OF INFORMATION FLOW FOR AN AUTOMATED BATTLEFIELD COMMAND AND CONTROL SYSTEM

This segment of the study is concerned with the (1) revision and expansion of the provisional SOP guidelines;[2] and (2) evaluation methodology and criteria. The methodology for evaluating the guidelines was planned originally (1978) to use hardware and software prototypes in a field test environment. When it became apparent that such prototypes would not be available as expected, a generic automated battlefield command and control system (ABCCS) was described in the form of a mathematical model. In order to use that model to study the Tactical Operations System (TOS), its parameters were quantified from the developing system design to be representative of TOS as it might have been fielded. The evaluation criteria were developed jointly with the division TOS network model (summarized in section 2.1). As a consequence of that research, the revised and expanded SOP guidelines were directed toward managing and controlling the demands imposed on each of the system components so as to avoid overloading any of them or, if one does become overburdened, to reduce the demand to a tolerable operating condition.

2.2.1 INTRODUCTION

The ABCC system passes information to the users and receives information and instructions from them. Many of the instructions are for the purposes of managing or controlling the use of the system, including its supporting communications, for one or more of the following reasons:

- a user/subscriber is overburdening some portion of the system;
- the tactical environment is degrading the system's capability to perform; or
- the system is overburdening some user-operator or user-subscriber.

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[2] Guidelines for Information Management in the Tactical Operations System (TOS): Provisional Standard Operating Procedures (SOP), VRI-ARI-3 FR-79-1, Vector Research, Incorporated, May 1979.

Each of the above situations requires some form of management control and is occasioned by the capacity of some component of the extended system being less than sufficient to accommodate the demand being placed upon it. For managing any type of ABCC system, alternative procedures can be devised for controlling the quantity of information handled by a given component. Human judgment, though, is essential for choosing which alternatives are most desirable in a given situation. Inherent in this management process is maintaining the quality of both the information flow and the data base as the quantity of information is reduced. Also, it is necessary that the system manager be able to discern that a problem exists, and why. This requires that the status of the system, both as whole and for each of its components, be monitored continually and provided to the responsible manager. Proper provisions for monitoring the status of ABCC system components to include the network links of the supporting communications system must be included in the ABCC system hardware and software designs. The monitoring capability is the interface between the ABCCS proper and the system manager. If it is not an explicit part of the design, but is left to field expedients, the most clever of those ad hoc methods may still be inadequate for tracking the status of the system. To demonstrate the necessity of including considerations for managing as part of the system design, TOS, as it might have been described in November 1979, is used here as an example of a contemporary ABCC system.

2.2.2 MANAGEMENT PROCEDURES AND MANAGEMENT PROBLEMS

The management control procedures which have been identified and investigated for controlling the burden of demand on various system components of TOS include: (1) reducing the number of incoming message retrieval requests; (2) changing the operating level of TOS users; (3) purging; (4) removing user(s) from distribution lists; and (5) altering the current level of hierarchical review. The choice of which management procedure(s) to implement requires knowledge of the strengths and side effects of the procedures, knowledge of the cause of the problem, and knowledge of the information needs of each TOS user. This discussion provides this information and the data and related statistics which need to be available to understand if a particular procedure would be effective in dealing with the problem. It is assumed that the person(s) responsible for controlling the system have knowledge of the users' information needs or that that knowledge can be easily obtained.

The system controller (SYSCON) is the overall manager of information processing in TOS, coordinating the technical capability of TOS and the operational need of its users. In this discussion the SYSCON is assumed to be totally responsible for the management of TOS, although it is recognized that the file managers and the TOS users could be involved in the management process. This involvement would likely result in increased satisfaction of the users with the necessary management action and a decrease in the burden on the SYSCON to perform the management task.

Reduction in the number of incoming message retrieval (IMR) requests, the first procedure given above, will affect the demand placed on the communication nets and the TOS users by reducing the number of responses to the IMR requests--SRI, thresholds, correlations, and filters--which are transmitted over the links and the number which need to be assimilated by the users. The

demands placed on the computer processors are affected by the consequent reduction in the number of criteria which must be tested, the number of data base searches, etc. Some of the factors which determine the magnitude of the effect on each of these TOS components include the frequency that the IMR criteria associated with the deleted request are tested, the frequency that data base searches are required, and the number of responses which are generated from a satisfied request.

The second procedure is a tool with which the SYSCON can control the inputs (updates and queries) to the system. In the examples described, a system of four operating levels is used to control the demands placed on the system. To determine the effect of reducing the operating level the SYSCON needs to have knowledge of the current operating status (the actual numbering updates and queries submitted) of each user and the operating level guideline for each user.

The third procedure, purging, is primarily effective in rectifying a computer storage overload. The procedure includes methods for eliminating irrelevant and outdated records from the data base, and methods for eliminating records in response to an indication that a file is too large or an impending overload. In order to recognize when this latter method of purging is necessary, the SYSCON needs to monitor the size of each of the files and alert the file manager(s) as to when they are becoming too large. Further the SYSCON and file manager(s) will need to be aware of the amounts and types of messages contained in these files in order to be sure that the purge is effective and timely in correcting the overloaded state of the data base disk.

Removal of a user from a distribution list will reduce the DCC output load, resulting in a reduction of the demand placed on users to assimilate the output messages, a reduction in the utilization of the communication links over which the messages travel, and a reduction in the utilization of some of the computer processors. The factor which determines the magnitude of the impact of this action on the TOS components is the frequency at which that particular distribution list is referenced.

The fifth management procedure identified as effective in rectifying overload problems is to alter the current hierarchical review practice. Hierarchical review allows the brigade element to review for possible alteration or deletion messages originating at a subordinate battalion. If a message is changed or deleted, a copy of the message is sent to the originator. The process reduces demands placed on the communications link between the DCC and the BDE, as some messages may be deleted by the review. Consequently, the demands on the computer processors are also reduced as the arrival rate of messages is decreased. However, the communications nets between BN and BDE are further burdened by hierarchical review due to the notification sent to the originator of deleted or altered messages. Therefore, altering a hierarchical review practice may be helpful in addressing an overload problem. In order to determine if the procedure will be effective in addressing a problem, the SYSCON will need to know the frequency that messages originating at BN are reviewed at BDE, the frequency with which those messages are changed, and the frequency with which they are deleted.

The five procedures discussed above are tools the SYSCON can use to control the quantity of information transmitted and stored by TOS. Depending on the component which is overloaded, the SYSCON would have a choice within this set of management procedures for the procedures which best alleviate the problem. For example, a storage overload is perhaps most quickly alleviated by purging, but also may be resolved by decreasing the operating levels of users. The choice among these procedures as to which are most effective depends on the circumstances causing the overload, the consequences of the overload, the current battlefield situation and the role of TOS and each TOS user in supporting the mission. For example, if a particular unit is in actual contact with the enemy, then it is likely they are providing reports which are of value to division commanders and a reduction in their access to send information is not appropriate. Also, the effects of the implementation of a management procedure on the quality of information of IMR requests, particularly the number of thresholds, correlations, and filters is likely to decrease the quality of the records stored in the data base as these functions allow analysts to process data records into information and intelligence which is more complete, accurate, and meaningful. The SYSCON must be able to examine the reduction in demand which can be realized by the implementation of each management procedure and then trade off the effects of implementing the procedure on the quality of information in order to make effective management decisions in maintaining the TOS system in an operationally viable condition.

2.2.3 METHODS FOR DIAGNOSING AN OVERLOAD OF A TOS COMPONENT

Methods for analyzing an overload in order to decide on the appropriate management action have been described, now the discussion focuses on what conditions constitute an overload and how one is detected. The term overload has been used to identify when the SYSCON needs to take management action to ensure that the TOS system remains responsive to users' needs and that a system crash is avoided. Thus, overload refers to a state of the component where its utilization is above some desired threshold. The determination of the appropriate threshold value is complex and needs to consider three basic factors: (1) the responsiveness that is required of the system; (2) the means by which the utilization of a component is measured; and (3) the procedures which are available to circumvent the problem.

The responsiveness that is required of the system includes the utilization which can be tolerated by the hardware and software without causing a system crash and the utilization which can be tolerated by users interfacing the system. A definition of overload suggested by the concept of operational capacity presented by the analyses of the TOS system (see section 2.1 of this chapter) considered primarily these requirements. Operational capacity is defined by this analysis as the demand which produces a utilization of 80 percent.

Factors which might necessitate that this threshold be lower are the means by which the utilization of the component is measured. If the utilization is computed automatically by computerized monitoring of busy and non-busy periods, then the primary concern is the period of time over which the utilization is measured. If the utilization must be measured by some other more

manual means, concerns such as the degree to which accurate data on the use of the system can be obtained, and the amount of manual effort required to calculate the utilization become more important when determining the appropriate threshold value.

The third factor is the quantitative relationship between the cause of the problem and the procedure for correcting the problem. For example, if a disk controller is being tasked to perform more jobs than it can handle, an appropriate management procedure might be to reduce the number of jobs arriving at the controller. The time it takes to complete each job, the number of jobs "backlogged," the time it takes to implement the management procedure, and the new rate at which jobs are arriving all impact the time it takes for the processor to return to a state where jobs are being processed in a timely manner. In determining the appropriate value of the threshold, these factors must be considered so that a system disaster is not incurred between the time the overload is detected and the time the effects of the management action are seen.

With the conditions determined for when a net is identified as overloaded, the SYSCON can use this guideline to determine when the employment of management controls are necessary. The SYSCON is responsible for monitoring the TOS components and determining the state of overload. The simplest way would be to have automatic monitoring of the components to determine the utilization, and once the threshold is exceeded, the SYSCON would be notified, either by a warning message or signal. Barring any sort of automation the SYSCON is still able to estimate the utilization of the TOS components. For example, the utilization of a communications net can be estimated by sampling for busy or non-busy status and calculating the fraction of time the net is found busy. Data which needs to be made available in order for the SYSCON to make this estimate includes the number of times the net users attempted to obtain the net (number of sample points) and the number of times the users attempted, but found the net busy.

Two basic types of monitoring of the TOS system are needed to effectively manage the system: monitoring to diagnose the component overload problem and monitoring in order to understand how to rectify the overload problem. Within this second type there are three kinds of statistics: those which describe how each type of demand (update, query, etc.) affects each type of component, those which describe the current load (demand) on each component, and those which measure the impact of the load on each component. In addition it is also necessary that the system manager has knowledge of the information needs of each user of TOS within the division and the methods by which these users obtain their information needs for ensuring that the users remain satisfied with the management control. The monitor statistics which are needed to diagnose an overload of the system are dependent on the degree to which the hardware and the software of the system automatically monitor the status (utilization) of each component. Once the overload is detected, data describing the demands placed on the system and how these demands impact the system need to be available in order to determine the appropriate management action. Example monitor statistics developed in this study are listed in exhibit 2-17. The number and variety of items which must be monitored in order for the SYSCON to control the system exemplify the need for a provision for this monitoring capability to be included in the hardware and software

EXHIBIT 2-17: EXAMPLE MONITOR STATISTICS

STATISTICS FOR DETERMINING THE LOADING ON TOS COMPONENTS:

For Each User:

- IMR Requests Originated
  - SRI (Standing Requests for Information)
  - THRESH (Thresholds)
  - CORR (Correlations)
  - FILTER
- IMR Responses Received
  - SRI (Standing Requests for Information)
  - THRESH (Thresholds)
  - CORR (Correlations)
  - FILTER
- Updates Originated
- Updates Response - Total
- Update Responses - Received via D/L (Distribution Lists)
- D/L a Member of
- Queries Originated
- Messages Altered or Deleted by Hierarchical Review
- Operating Level Guidelines

STATISTICS FOR DETERMINING THE IMPACT OF DEMANDS ON TOS COMPONENTS:

Demand: Incoming Message Retrieval (IMR) Requests

(SRI)

- Number of SRI on the system
- Frequency that IMR criteria for SRI are checked
- Frequency that IMR criteria for SRI are satisfied
- Distribution of SRI response
- Length of SRI responses

(THRESH)

- Number of Threshold queries on the system
- Frequency that IMR criteria for correlations are checked
- Frequency that IMR criteria for threshold queries are satisfied
- Frequency that threshold criteria are satisfied
- Distribution of threshold responses
- Length of threshold response
- Average number of keys and key values searched

(CORR)

- Number of correlations in the system
- Frequency that IMR criteria for correlations are checked
- Frequency that IMR criteria for correlations are satisifed
- Average number of queries triggered
- Distribution of correlation responses
- Length of correlation responses
- Average number of keys and key values searched

-- Continued --

EXHIBIT 2-17: EXAMPLE MONITOR STATISTICS
(Concluded)

STATISTICS FOR DETERMINING THE IMPACT OF DEMANDS ON TOS COMPONENTS:
(Concluded)

- Number of filters in the system
- Frequency that IMR criteria for filters are checked
- Frequency that IMR criteria for filters are satisfied
- Frequency that a data base search is triggered
- (FILTER) Frequency that a filter response is required
- Distribution of filter responses
- Length of filter response
- Average number of keys and key values searched

Demand: Update Messages (Add, Change, Delete)

- Frequency that messages are originated
- Distribution of messages by type (ESDA, ESDC, UTOD, etc.)
- Length of message
- Number of keys updated
- Distribution associated with messages

Demand: Queries

- Frequency that queries are originated
- Length of query
- Distribution of query response
- Length of query response
- Number of keys and key values searched

design. If it is not an explicit part of the design, but is left to field expedients, the most clever ad hoc methods may still be inadequate for tracking the status of the system. The extent to which the management interface should be designed is governed by two major considerations: (1) the magnitude of the system control tasks which are left for the system manager to perform; and (2) the type of status information or the detail necessary for effective performance of those system control tasks. Further, as indicated by this study, these two considerations are likely to change together: if the management tasks become large, so will the amount of information necessary to be monitored, and vice versa.

2.3 SUMMARY OF ALL-SOURCE ANALYSIS SYSTEM (ASAS) DESIGN ISSUES

Experience with the development of battlefield automated systems, e.g., TSQ-73, TACFIRE, DS_3, and TOS has not been uniformly satisfactory. Schedules have slipped, costs have increased, and performance standards have been difficult to achieve. A significant reason for this is that these command control systems operate in a process which is highly variable, dependent upon individuals, and not completely understood. However, problems have also arisen with the interfaces among these systems and between the systems and other components of the total command and control process. Paramount among these problems is the fact that existing communications will not support input, output, and exchange of data. This particular problem is further complicated by the dynamics of radio-electronic combat on the modern battlefield requiring high levels of resistance to jamming and intercept.

The ASAS system currently envisioned provides capacity but not coverage nor communications sufficiently adequate to fulfill its mission. It is possible that coverage and communication problems will be solved before the ASAS is fielded. The primary problems in the ASAS/ECS^2 interface stem from a lack of understanding of commanders' information needs and their relative values. Beyond this, problems with communications and interfaces among the components of the ECS^2 system will continue to pose a major stumbling block to successful systems development, both for the ASAS, and the ECS^2 as a whole.

2.4 GUIDELINE DEVELOPMENT FOR IMPROVING INFORMATION SUMMARIZATION IN A CORPS-LEVEL SCENARIO

2.4.1 INTRODUCTION

The technical capability of computer-based military systems could increase the density of information to the point where it will overwhelm the users. In particular, the Enemy Situation Data (ESD) file is likely to grow at a rapid rate during critical periods, such as during enemy attacks. Therefore, appropriate procedures must be developed to condense and to organize the volume of such information into a form that can be managed and used in an efficient manner.

To obtain data to support the development of useful guidelines for the summarization of military message content, particularly tactical intelligence data, an initial experimental investigation was conducted by Geiselman and Samet.[3] In their experiment, an attempt was made to first identify "good" summaries of a set of ESD messages, and then to analyze the properties and structural characteristics of these summaries. In brief, 16 Army staff officers were asked to examine a description of a tactical scenario and 30 ESD messages. The messages described the beginning of a border crossing and attack. The task was to rate each message in terms of how essential it was to the understanding of the situation at hand, and to summarize the tactical information contained in the messages in preparation for a three-minute briefing to the Corps G-2. The 16 summaries were then rated by five experienced military personnel. In this manner, the essence of what makes an effective summary was used to suggest guidelines for summarizing tactical data.

Three general guidelines for intelligence summaries were extracted from the results. First, they should be prepared in conversational style. Second, a well-founded interpretation of the information should be given if possible, not just hard facts. Third, a dynamic portrayal of the enemy situation should be offered to reflect the reality of the scenario; that is, information concerning enemy movement should be emphasized. However, before these guidelines could be implemented, empirical research was required to evaluate their effects upon summarization performance. Further research was also called for to compare these guidelines with those developed for the summarization of military messages reflecting other tactical situations, particularly an enemy-defensive scenario. In addition, one procedure that could be used to complement information summarization is purging, which can be accomplished in a number of ways including the "routine" or manual purge. However, to date there has been no systematic investigation of the substantive criteria to be used to conduct a manual purge. In this regard, guideline development would also be valuable.

Thus, there were three major objectives of the present research: (1) To expand the scope of the guidelines for summarizing ESD messages by examining a second basic tactical scenario in which the enemy is portrayed in a defensive posture; (2) To establish whether military personnel using summarization guidelines produce "better" summaries than do personnel without the aid of guidelines; and (3) To obtain data to support the development of guidelines for conducting a routine purge of ESD files. To address each of these objectives, a single experiment was designed. The first objective was addressed by asking two groups of staff officers to summarize a set of ESD messages while supplying one group with the three general guidelines developed by Geiselman and Samet. The second objective was addressed by modifying the enemy-offensive scenario previously used by Geiselman and Samet such that the enemy would be on the defensive and U.S. forces would be said to be engaged in a counterattack maneuver. The summaries and ratings of essentiality of individual messages were analyzed to derive a template or schema for summarization that could be compared with that derived using the enemy-offensive

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[3]R. E. Geiselman and M. G. Samet, "Information Summarization in a Corps-Level Scenario," U.S. Army Research Institute (Alexandria, VA), Technical Paper 385, October 1979.

scenario. The third objective was addressed by analyses of data collected during the final segment of the experiment. During that segment, the participants were asked to purge half of the intelligence messages (eliminating those that are least important) and to rank order the remaining messages on the basis of the importance of retaining them. These data allowed for the derivation of a template for reducing the size of ESD message files by varying amounts.

2.4.2 METHOD

Thirty-two staff officers were asked to read a description of a short tactical scenario and examine 30 ESD messages. The scenario was a modified version of that used by Geiselman and Samet where the U.S. Forces were said to have been attacked by Warsaw Pack Forces. For the present experiment, the U.S. Forces were described as being engaged in a counter-attack maneuver against the enemy. The participants' task was to rate each message in terms of how essential it is to the understanding of the situation at hand, and to summarize the tactical information contained in the messages in preparation for a three-minute briefing to the Corps G-2. Sixteen of the staff officers were given three guidelines to follow in preparing their summaries. These guidelines appeared in the instructions as follows:

(1) Prepare the intelligence summary in a conversational style. Do not present information in the form of lists alone since this makes understanding the information time-consuming and difficult.

(2) Provide an interpretation of the intelligence information if that is possible. In other words, in addition to the "hard facts," try to state what the intelligence means in terms of the enemy situation. However, these statements must be well-founded.

(3) Provide a dynamic portrayal of the enemy situation. That is, emphasize the speed and direction of enemy movement, rather than merely the current static position of enemy units.

The 32 hand-written summaries were typed and rated by seven knowledgeable military officers with relevant experience in terms of content, interpretation, accuracy, organization, and style. An overall evaluation of each summary was also collected from each rater.

Following the work of Kintsch and van Dijk,[4] it was assumed that a summary is representative of the summarizer's basis for evaluation and mental organization of the message content. This basis, which is an organized knowledge structure, or schema, provides a mental outline for the learner or user onto which the appropriate elements from the material to be learned can be "attached." Consequently, a major analytical task toward the development of guidelines for summarization was to extract a representation of the schema that was applied successfully to the messages by the staff officers in generating "good" summaries.

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[4] W. Kintsch and T. A. van Dijk, "Comments on Summaries of Stories," Languages, 1975, 40: 98-116.

Operationally, a schema can be defined as a two-dimentional, or hierarchical outline with the dimensions being subordination (importance) and sequential order. Subordination, or level in the "deep structure" of material, has typically been determined using derivational rules (e.g., a story grammar) applied directly to the full text, but this procedure is time-consuming and is often highly subjective. Fortunately, the subordination of information based upon derivational rules has been found to be correlated with the likelihood that a reader will include the information in a summary of the full text (Thorndyke).[5] Therefore, in the present experiment, as in the earlier Geiselman and Samet experiment, subordination, or importance, could be determined for each idea included in a summary in terms of the percentage of the staff officers that included some aspect of that idea in their summaries. That is, an idea with a higher inclusion percentage was assigned a higher position in the structure.

A list of general ideas or topics was extracted systematically from the "good" summaries such that the list exhausted the summary contents. The topics were identified by noting the authors' syntactical divisions (e.g., paragraphs, listings) and transitions in subject matter within these divisions. The topic labels were then taken from the identified summary segments. In this manner, a particular message could support one topic in one summary and an entirely different topic in another summary.

Sequential order was assessed by deriving an output-position percentile for each topic included in each staff officer's summary. The output-position percentile [(sequential position of a topic in a summary divided by the total number of topics included in the summary) X 100] is a measure of output position where the derived value is standardized with respect to the number of ideas in the respective output. Within each group of participants (guidelines, no guidelines), a median output-position percentile was computed for each topic.

To derive a schema, a median output-position percentile was computed for each topic that was included in at least one of the "good" summaries, and the subordination dimension was scaled in terms of the percentage of staff officers including a given topic in their summaries. The schema generated from the "good" summaries obtained in the present experiment, involving enemy-defensive activity, was compared to the schema derived by Geiselman and Samet for an enemy-offensive scenario. In addition, the essentiality ratings given by the present subjects were compared to those obtained by Geiselman and Samet.

A schema of the purging process was derived from the data collected during the final phase of the experiment in which the participants were asked to delete 15 of the 30 messages and to rank-order the remaining 15 messages on the basis of the importance of retaining them. To derive the schema, an inclusion percentage and a median rank order were computed for each of the 30 ESD messages that were retained by at least one participant. A point, representing each of the 30 messages, was then plotted in the two-dimensional space (inclusion percentage by median rank order).

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[5] P. W. Thorndyke, "Cognitive Structures in Comprehension and Memory of Narrative Discourse," Cognitive Psychology, 1977, 9: 77-110.

2.4.3 RESULTS AND DISCUSSION

The three guidelines appeared to have potent effects upon summarization performance. First, regarding interpretation, the participants with guidelines were more likely to include a statement at the beginning of their summaries about the overall strength of the enemy forces and a statement of inference concerning the enemy's intentions (retreat, delay, attack, etc.) at the end of their summaries. Regarding style, the participants with guidelines were less likely to present information in the form of a list. Regarding a dynamic portrayal of the enemy situation, the participants with guidelines were more likely to discuss enemy movement both away from the FEBA and toward the FEBA. Overall, then, the guideline manipulation did affect the content of the summaries and the specific effects were in agreement with the spirit of the guidelines. Further, there was significant interjudge agreement that the summaries constructed with the guidelines were "better," on average, than those constructed without the aid of guidelines. This result, which was obtained for four of the five evaluation scales, serves as validation both for the three general guidelines used here and for the basic experimental methodology developed by Geiselman and Samet. In addition, the fact that three simple guidelines can be used to improve the summarization of intelligence information has promising implications for the potential success of training programs in the area of tactical information management.

Several analyses were constructed to determine major points of departure in information selection and organization between scenarios. First, it was determined that the same types of ESD messages were considered to be most essential for the understanding of the enemy situation regardless of whether the enemy was depicted as being in an offensive or defensive posture. In each case, information concerning nuclear weapons, engagements, enemy movement toward the FEBA, and locations of regimental command posts were seen as most important. Thus, with respect to the selection of "hard facts," it does not appear that the enemy's presumed posture is a crucial factor, such that certain aggregate guidelines can be proposed concerning that distinction.

However, as noted by Geiselman and Samet, the integration of the "hard facts" in the form of overall assessments and inferences or battlefield indicators (Johnson),[6] is a process that would likely be affected by the nature of the scenario. The fact that information integration was influenced by the scenario was apparent in a comparison of the schema derived from the data in the present experiment with the earlier schema derived by Geiselman and Samet. With an enemy-offensive scenario, inferences concerning the location of the probable point of main thrust and the location of the second echelon were considered important. With an enemy-defensive scenario, these inferences were replaced by an inference regarding the enemy's likely intentions (retreat, delay, attack, etc.) and an introductory summary statement concerning the overall strength of the enemy forces. Thus, further work in the area of battlefield indications is crucial for the development of training programs toward the generation of effective intelligence summaries.

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[6] E. M. Johnson, "The Perception of Tactical Intelligence Indications: A Replication," U.S. Army Research Institute (Alexandria, VA), Technical Paper 282, September 1977.

Aside from differences in the inferences made in the context of each scenario, the schemata were quite similar. Three levels of detail (subordination) could be clearly discriminated within the schema in each case, and these three levels could provide a basis for specific guidelines regarding content and order of presentation for general and more detailed summaries. At the most general level, a summary should include only information of immediate threat to friendly forces, such as engagements and enemy movement toward the FEBA, plus an inference regarding the enemy's immediate intentions. At the next level of detail, an introductory summary statement concerning overall enemy strength should be included plus a discussion of enemy units of less importance behind the FEBA (e.g., support units, air defense, rear unit movement). At the most detailed level, a summary could further include ancillary information such as the location of the second defensive belt, instances of radio jamming, and locations of command posts as targeting information.

A two-dimensional schema of the results of the purging task was also derived, and it was apparent that the schema was linear in form rather than hierarchical; that is, the correlation across messages between the inclusion percentage dimension and the median rank order was -.89. Further, the ratings of message essentiality collected at the beginning of the experiment accounted for 80% of the variance in the inclusion data from the purging task. Thus, the participants appeared to base their decisions regarding the purging of the ESD file almost exclusively upon their perceptions of the essentiality of the messages. This was true even though the essentiality ratings were collected by the experimenter prior to the purging task. What is particularly striking about this finding is that the high degree of correlation between the essentiality ratings and the probability of retention of a message in the purging task was obtained regardless of whether a participant was given guidelines in the preceding summarization task or not. Thus, certain ESD messages were perceived to be essential to the comprehension of the tactical situation, and there was considerable agreement among the staff officers concerning these perceptions. As noted by Geiselman and Samet, who also found substantial agreement among officers on ratings of the essentiality of messages, the Army appears to be imparting a common core of knowledge to its officers about the need for information of various types. Hence, it is in the areas of information organization and integration that a considerable amount of research effort should be expended.

2.4.4 CONCLUSIONS

The results of this investigation support the development of guidelines for the summarization of tactical intelligence information, and provide valuable insight concerning the content and structure of those summaries that are likely to be judged effective in the communication of information contained in an ESD message file. Staff officers utilized three general guidelines developed in the first of this series of studies to produce more effective summaries of intelligence messages, thus validating the guidelines. Further, the content and organization of summaries judged to be "good" were found to be basically the same regardless of whether the posture of the enemy was portrayed as offensive or defensive. This implies that the number of variations of schemata, and thus specific guidelines needed to describe ESD files, might be relatively small--such that standard routines could be developed

and operationalized to support message-summarization efforts. However, significant differences between scenarios were identified in terms of information integration and inferences; and therefore, further research on battlefield indicators seems warranted. Additional research is also called for to evaluate the impact of guidelines for information management on tactical decisionmaking, and to investigate the degree to which these guidelines can be generalized to the summarization of other forms of military messages (e.g., friendly situation data).

2.5 DETERMINING DECISIONMAKER'S INFORMATION REQUIREMENTS (Interim summary of work in progress)

Research to analyze and develop approaches to determining decisionmaker's information requirements is currently in progress. Two parts of the draft report, one developing an approach to the problem and the other surveying techniques described in the available literature, have been produced. These two documents are summarized in this section. A third part, still in preparation, is oriented on the current state of knowledge and thinking about divisional and corps commanders' information needs. These papers are planned to be consolidated into a formal report during July 1980.

2.5.1 A METHODOLOGY FOR DETERMINING A DECISIONMAKER'S INFORMATION REQUIREMENTS

This draft paper analyzes how a division commander and his staff assess the commander's information needs. The study was fundamentally different from many which have been performed previously. The prior analyses postulated an operational situation and then examined the question of what information would a commander need to operate successfully in that situation. The investigation topic for this research was more fundamental: For a given situation, how does the commander and his staff determine the required information?

The approach was to postulate a six step model which describes a decision paradigm which a commander could follow. This paradigm includes the actions of the commander and his staff and displays the interrelationships between the various activities which would occur at division headquarters during combat operation. These six steps were monitoring the situation, modeling situation, constructing alternatives, projecting the courses of action by both sides, consequences of each set of actions, applying judgment criteria to the projected outcomes and make decisions, and issue orders.

The research involved describing the activities which occur in each of these basic steps in successively finer levels of detail until a level was reached at which information requirements could be uncovered. This breakdown involved examining the sources and types of information, the types of monitoring and decisionmaking which occur, and discusses in some detail the various types of data which are produced and utilized in decisionmaking.

The product of examining the detailed breakdown of the decision paradigm was the identification of three basic types of data which are required by a division commander. These data are grouped into the situation data, philosophical data, and value data. Situation data pertain to the physical and operational situation which confronts the commander. Physical data consist of terrain and meteorological data as well as order of battle and deployment information concerning both the friendly and enemy forces. Philosophical data pertain to the enemy commanders and are used to determine possible and probable courses of action. Value data are similar to the philosophical data; however, they pertain to the friendly commander. The value data are utilized by the commander's staff to assist in determining the type of data the commander desires.

Examination of the contents of these data sets indicated that the philosophical and value data are static with respect to the given operation and can be gathered well in advance of their need. It is also the case that many of the situational data, such as terrain and meteorological data, are static with respect to the division commander's time frame and thus can be gathered prior to commencement of operations. The operational data pertaining to deployment and order of battle, however, are highly time perishable and it is these data which must be provided and updated frequently.

The analysis provided a means of modeling the information gathering, processing, and disseminating activities of a division headquarters, identified the types and uses of data, and provided a means whereby a commander's staff can translate the characteristics of a given operational situation into the required information that its commander would need.

2.5.2 SUMMARY OF A SURVEY OF METHODOLOGIES FOR DETERMINING A DECISIONMAKER'S INFORMATION REQUIREMENTS

This draft paper reviews a variety of methods to determine and organize a commander's information requirements. Methodologies from ARI and the civilian sector are reviewed. Some of these approaches may be directly useful in defining a commander's information needs while others may serve as a starting point for further studies.

Four procedures created by or for ARI address the specific problem of a battlefield commander. They are based on the use either of survey questionnaires or of simulation exercises. McKendry, et al., uses a comprehensive survey tool to obtain answers to the question of what information officers believe they need. Strub and McConnaughey ask officers to request information in an environment where planning stages for tactical operation are simulated. The results offer clues as to the relative importance of certain information to the commander. Krumm uses the same simulation to test the validity of Strub's and McConnaughey's methodology. Coates and McCourt survey officers to collect results on the relative significance of order of battle elements to the commander. Their results expand the body of information needs identified by officers.

Six methodologies designed for business managers or for other decisionmakers are also reviewed. They are included for their ability collectively to provide a representative cross-section of those methods currently available for study. The sample does not pretend to be an exhaustive list of every method available for determining a decisionmaker's information needs. Taggart offers a comprehensive syntactical approach, based on the analysis of words, to the problem of identifying information needs. McDonaugh decides that information requirements are derived first by focusing on and then by analyzing selected management problems. Heany concentrates on the decisionmaking responsibilities of the manager as the starting point for any search for specific information requirements. Altman systematically offers a six stage procedural analysis of the system, its functions, and how they are allocated as a way to uncover the information needed to make accurate decisions. The problem of documenting information needs is attacked by Tiechroew. He offers the Problem Statement Language, a computer-aided language that uses objects and relationships to describe a system's boundaries and its content. Miller employs a conceptual approach designed to deal with mental abstractions that present major obstacles to managers and analysts when they attempt to determine information requirements.

Three of these six methods are analyzed for the role a decisionmaker is expected to play in them. Some approaches restrict the decisionmaker to descriptive contributions while others require that he fulfill important analytic responsibilities.

Lastly, an operations research approach to the problem of determining a commander's information needs is presented. This is an example of how general methodology can be applied to this particular problem. Kleist models the operational environment confronting the organization. His particular model breaks down the commander's decisionmaking process so that areas where information is needed can be located.

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